MARBLE

Art Historical and Scientific Perspectives on Ancient Sculpture

M A R B L E

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Papers Delivered
at a Symposium Organized
by the Departments of
Antiquities and
Antiquities Conservation
and Held at the
J. Paul Getty Museum
April 28–30, 1988

The J. Paul Getty Museum
Malibu, California
1990

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Library of Congress Cataloging-in-Publication Data:
Marble: art historical and scientific perspectives on ancient sculpture.
p. cm
Papers delivered at a symposium held at the J. Paul Getty Museum, April 28–30, organized by the Departments of Antiquities and Antiquities Conservation.
ISBN 0-89236-174-3
1. Marble sculpture, Ancient—Congresses. I. J. Paul Getty Museum. II. J. Paul Getty Museum. Dept. of Antiquities. III. J. Paul Getty Museum. Dept. of Antiquities Conservation.
NB1210.M3M28 1990
733—dc20 90-42216

Project staff:
Editors: Marion True and Jerry Podany
Manuscript Editor: Benedicte Gilman
Editorial Assistant: Mary Holtman
Design: The Sheila Studio
Production Coordinator: Lark Zonka

Typography by Wilsted & Taylor
Printed by Alan Lithograph, Inc.

Cover: The Peplos Kore (detail). Athens, Akropolis Museum 679. Photo: DAI Athens

ISBN 0-89236-174-3

Contents

Foreword

These papers on ancient marble sculpture were read at a two-and-a-half-day meeting held at the Getty Museum in April 1988. The meeting was the second of a series of international symposia begun in 1986 by our Antiquities department with a gathering on *The Amasis Painter and His World* and followed by others on *Small Bronze Sculpture from the Ancient World* (1989) and on *Chalcolithic Cyprus* (1990).

The symposium on marble was prompted not only by scholarly curiosity but also by frustration. The Getty's curators and conservators, like others who work on stone sculpture, are often handicapped in their efforts to date and locate a piece by the lack of firm evidence about the provenance of marble, the working techniques of ancient sculptors, and the age and nature of surface incrustrations – all of which might reinforce the judgment of the trained eye and mind. Knowledge about marble is imperfect, and those who have parts of it are found in widely disparate fields. The issues seemed important enough to justify a meeting that would bring together people from various disciplines: archaeologists, classicists, conservators, scientists, and sculptors came to discuss studies in progress. The subject was not the spiritual glories of Greek sculpture but rather the more practical properties of marble itself – its origins, its travels, its uses, the changes it undergoes with the passage of time – and how these might affect our judgment of the pieces made from it.

I am grateful that the symposium gave us yet another chance to collaborate with our sibling institution, the Getty Conservation Institute, whose staff aided us in many ways. We thank the authors for having been prompt with their papers and patient in awaiting their publication. Finally, I want to acknowledge the essential role played by the Curator of Antiquities, Marion True, and the Conservator of Antiquities, Jerry Podany, as well as the staffs of the Departments of Antiquities and Antiquities Conservation in organizing the symposium and helping to see this book through to print.

John Walsh
Director

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Disiecta Membra: The Remarkable History of Some Sculptures from an Unknown Temple

Angelos Delivorrias

To Ulrich Hausmann for his encouragement and generosity

The complex problems concerning ancient Greek sculpture are more readily appreciated through a concrete example than through theoretical exposition, no matter how complete. I therefore take the opportunity to discuss, and open up for discussion, a group of under-life-size marble statues, which, now scattered in various collections in Europe and America, very probably together belonged to the architectural adornment of an otherwise unknown late Classical temple somewhere in Greece. These puzzling *disiecta membra* of the dismantled ensemble have had and continue to have a remarkable history: Transported in antiquity as a group to Rome where, still together, they probably decorated the triumph of a Roman general returning home from the wars, they must later either have been transferred to one of the famous Roman gardens or reused as architectural sculpture for a temple. They remained together in Rome until the Renaissance, when they reappeared, only to be dispersed.

To my eyes each member of this group is linked to each of the others in manifold ways. Yet an embarrassing archaeological controversy has developed in regard to their original appearance, to their exact position in the architectural composition, to their style, dating, iconography, and attribution. Nevertheless the range of proposed interpretations and the diversity of opinions reveal not so much the inability of the art historical approach to provide definite answers as something more important: the fragmentary state of our knowledge of antiquity, particularly in regard to culture, and especially art. In other words, neither the method nor its practitioners are to blame, but rather the gaps in our knowledge of the tradition of ancient Greek art. The fact that the art historical investigation of these sculptures has hitherto led to no satisfactory results may be regarded as a challenge to our scientific colleagues, whose assistance here would be welcomed. In spite of my faith in the traditional art historical method – i.e., structural and stylistic analysis of form – I am well aware of the skepticism, even mistrust, it encounters. So I harbor no illusion that there is any way to prove the common origin of these sculptures other than petrographic, chemical, and isotopic examination of their marble.[1]

FIG. 1a

Peplos-wearer. Front. Paris, Musée du Louvre MA 3072. Photos: Chuzeville.

FIG. 2a

Chiton-wearer. Front. Paris, Musée du Louvre MA 3516. Photos: Chuzeville.

I begin my presentation with the two well-known running girls in the Louvre, first published by Charles Picard (figs. 1a–d, 2a–d), who argued that from the point of view both of style and composition they had originally belonged together, and managed to trace them back to Rome.[2] In the early nineteenth century the statues appear in the collection formed *manu militari* by Napoleon's governor, Comte Sextius Alexandre François Miollis (1807–1814), flanking the entrance to the casino of his residence in Rome, later known as the Villa Aldobrandini.[3] Later they were transferred to the Villa Lante in Rome, where they were noted by F. Matz and F. von Duhn[4] and misleadingly sketched by P. Weber.[5] Georg Lippold traced their presence in Rome further back, into the late sixteenth century, by identifying the figure running to the left (figs. 2a–d) in a drawing by the French sculptor Pierre Jacques, dated 1576 (fig. 3).[6] Since Jacques' drawing shows this figure with head and both arms restored, it would be reasonable to assume that the artist must also have seen the second figure, running to the right (figs. 1a–d), but, noticing that the entire upper part of her body was new, he chose not to draw her.[7]

Picard suggested that the two figures were lateral akroteria and attributed them to the Doric temple of Apollo at Bassae. This idea was welcomed by W. B. Dinsmoor, who had previously conjectured that both the pedimental sculpture and the akroteria of the temple had been transported to Rome in ancient times.[8] Charline

FIG. 1b

Right side of peplos-wearer, figure 1a.

FIG. 2b

Left side of chiton-wearer, figure 2a.

Hofkes-Brukker supported the Bassae theory, arguing that the so-called Apollo in Copenhagen (figs. 4a–d), which Adolf Furtwängler had previously recognized as an akroterion, belonged to the same composition (fig. 5).[9] In this connection it is interesting to note that she avoided naming the two girls, merely stating that their vigorous motion precluded their identification either as Artemis and Leto or as the Muses, and she dismissed any idea that they might represent nymphs, Charites, or Horai; in fact she went so far as to conclude that ". . . es scheint wohl klüger, sich für die Mädchen nicht auf einen bestimmten Namen festzuhalten."[10] Picard had already argued against earlier identifications of the two female figures either as dancers or as Nikai. He hesitated between two interpretations, one as spectators of the drama in Niobe's palace, the other, more probable one, as companions of a nymph seized by Apollo.[11] Old ideas have, nevertheless, an amazing stamina,[12] and, in addition, new awkward proposals are being added to the already rich collection of possible identifications.[13] The current tendency to ease the problem of identification with neutral appellations such as "girls," "Mädchen," or simply "figures" bears witness to a sad truth: As long as we are not able to decode the meaning of a sculptural form, we can hardly expect to understand the rest of its complicated significance. This seemingly categorical statement also holds true for another interpretation which, as far as I know, has been put forward only once up until now: a tentative suggestion that the Louvre figures might

FIG. 1c

Left side of peplos-wearer, figure 1a.

FIG. 2c

Right side of chiton-wearer, figure 2a.

represent some female personifications.[14]

Some years ago I suggested that in order to find out what an unidentified lateral akroterion means without detouring around the problem by naming it after an abstract concept, it is necessary to know the original composition of the central akroterion.[15] However, most floating figures, whose original context is unknown, are still interpreted as abstract concepts,[16] which could also hold true for the Louvre figures (figs. 1a–d and 2a–d), for they have not yet been satisfactorily linked to a specific central element. Although the so-called Apollo in Copenhagen (figs. 4a–d) has been proposed as their missing escort, the three figures are not linked either by style or by movement, nor by any possible affinity that would suggest that they could have formed a triad.[17] Whereas the "Apollo" is represented self-contained, the female figures are shown in violent motion both physically and psychologically, implying that they were originally involved in a more dramatic event than the "Apollo."

Some elements in the rendering of the male figure evoke an erotic mood – quite foreign to the established iconographic repertory for the god – which has no answering traits in the bearing of the running girls. The so-called Apollo requires an entirely different company. The emphasis on the genitals, unusual in ancient Greek works of art, especially in Athens,[18] is a phenomenon that is fairly well known in the more sensual art of the hellenized East.[19] The

FIG. 1d
Back of peplos-wearer, figure 1a.

FIG. 2d
Back of chiton-wearer, figure 2a.

extraordinary richness of his windblown garments furthermore suggests that he might represent a bridegroom just arriving from the East, where the ependytes, which seems at first glance surprising, was worn more frequently on ceremonial occasions than in Greece.[20] The identification of this figure as Apollo, based on dubious iconographic criteria, is certainly open to question,[21] while its deviations from the standard iconographic tradition of Apollo must account for its otherwise inexplicable appraisal as a "römische Erfindung."[22] I would prefer to suggest that the Copenhagen figure could be identified with Paris, indirectly reflecting the way in which Euripides might have imagined the Trojan hero: The oriental prince who was privileged to judge divine beauty, symbolizing the ultimate cause of the Trojan War, might well have been shown at the very moment when he arrived from the East, the wind still blowing his luxurious garments;[23] he might even have held a kithara, as if in conscious allusion to music as one of the many aspects of his seductive charms.[24]

Taking the above considerations into account, the two running girls in the Louvre should be dissociated from the Copenhagen kitharist. They have nothing to do with the Bassae temple, which was decorated with floral akroteria, as has been shown by F. A. Cooper[25] and accepted, apparently, by Hofkes-Brukker, who in her latest discussion of the Bassae frieze mentions one of the two running girls, but not in respect to its architectural function.[26]

A thorough comparison of the two figures of running girls to each other may reveal their original function; it may also help us reconsider whether they have been intended for a pediment rather than lateral akroteria, as suggested by E. Mishon[27] and by F. P. Johnson, who independently of Picard had attributed them to the Bassae temple and identified them as Niobids.[28]

It has correctly been noted that akroteria and pedimental figures have in common a structural peculiarity: they are often shallow and appear two-dimensional because of space restrictions and the need to reduce their weight as much as possible. Yet the akroteria, in contrast to the pedimental figures, were meant to be seen not only from the front but also from the side, and partly from the back as well. This is why some years ago I assumed that all lateral akroteria of riding figures must have been centrifugally composed, for otherwise the spectators' eyes would first have been drawn to the animal's buttocks.[29] This principle must have governed the compositions of the Dioskouroi from the Ionic temple in Epizephyrioi Lokroi,[30] of the nereids from the Athenian temple of Ares,[31] of the nereids from Formia in Naples,[32] and of the figures from the west side of the temple of Asklepios in Epidauros.[33]

FIG. 3
Drawing of the Louvre chiton-wearer by P. Jacques, 1576 (from Reinach, *L'Album de Pierre Jacques*, pl. 50).

Nevertheless an akroterion and its base could occupy a much deeper space than a pedimental figure on the horizontal geison. On the other hand, the exaggerated two-dimensional form characterizing the main view of the lateral akroteria on the temple of the Athenians at Delos (figs. 6a, 7a) has no effect on the three-dimensional volume of the side views (figs. 6b, 7b),[34] so it should not be taken as a general rule applicable to all earlier and later examples.[35] With this in mind, it would be well to examine the structure of the Louvre figures in more detail, focusing on the question of whether they are really compatible as sculptural counterparts.

The outer side views of the two girls are strikingly different with respect to the treatment of volume: The peplos-wearer (fig. 1b) is clearly more massive, whereas the chiton-wearer (fig. 2b) has been fitted into an extremely confined frame, like a flat slab of marble with relatively little depth. The same holds true for the inner side views (figs. 1c, 2c), although here the effect is considerably decreased by the fact that the lower edge of the peplos worn by the former figure was later recut and no longer floats free. This technical feature, the importance of which I shall return to later on, can better be appreciated in the back views (figs. 1d, 2d), which show that the chiton-wearer was already thin enough for all practical purposes and did not need to have her volume further reduced. Thus it is reasonable to assume that only the peplos-wearer was an akroterion, while the second figure, with its

FIG. 4a

"Apollo." Front. Copenhagen, Ny Carlsberg Glyptotek 497. Photos: Ny Carlsberg Glyptotek.

FIG. 4b

Back of "Apollo," figure 4a.

FIG. 4c

Right side of "Apollo," figure 4a.

FIG. 4d

Left side of "Apollo," figure 4a.

unfinished back, was intended to be seen only from the front, and consequently more probably belonged to the pedimental composition of the same building. Moreover, the weathering on the peplos-wearer is slightly heavier than that of the chiton-wearer, indicating that the latter was in a more sheltered position. Since both figures are much better preserved than the Delos akroteria (figs. 6a–b, 7a–b), which remained in place throughout ancient times, they must have been removed, together with their companion pieces, at an early date. The *disiecta membra* from the Apollo Sosianus temple, recently reassembled by E. La Rocca, provide

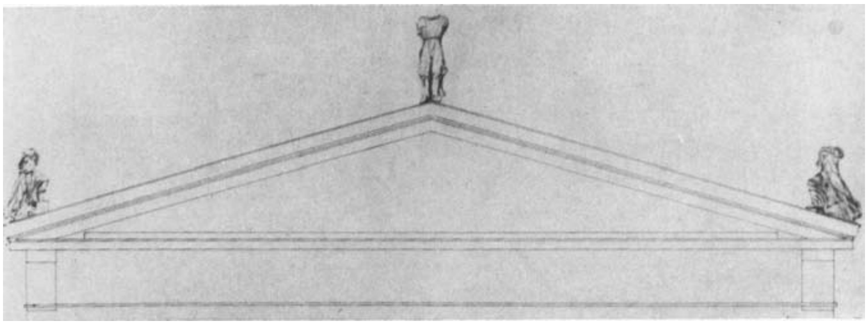


FIG. 5

Drawing showing how the Louvre and Copenhagen figures may have been placed on the temple of Apollo at Bassae (from Hofkes-Brukker, fig. 1).

a dramatic example of how a whole group of architectural sculpture was dismantled in antiquity and transferred from Greece to Rome.[36]

There is a series of indications that the Louvre figures were not set up as counterparts, although they were, obviously, parts of the same sculptural program. These indications should not be considered and criticized as isolated arguments, but should be seen as mutually reinforcing each other, thus producing a coherent whole greater than the sum of its parts. For instance, the difference in the height of the figures constitutes major evidence that they were not designed to adorn corresponding parts of the building. Indeed, the height of the peplos-wearer, including her modern upper torso, is 1.13 m, whereas the better preserved chiton-wearer is only 0.96 m high. Such a discrepancy would have violated the principle of balance ruling the composition of Classical architecture. Picard had certainly noted the difference in height, giving a facile explanation that also covers an entire range of other discrepancies: "L'artiste a su varier deux figures présentées en 'pendant' sur le même temple, mais il leur a laissé une unité de famille."[37] On the other hand, according to Hofkes-Brukker this difference is due to the elongated proportions of the modern upper torso of the peplos-wearer, and the disturbing asymmetry was in fact reduced in her restoration (fig. 5).[38] The fact that the plinth is missing also reduces the height of the chiton-wearer. But even taking these circumstances into consideration, the difference in height cannot be explained away on the basis of the state of preservation; it is due rather to the fact that the two figures were designed to occupy different positions on the temple. The peplos-wearer, whose foot is raised on a much higher level, can be understood as rushing forward, magnetized by the force of an unknown event represented at the apex of the temple. In contrast, the movement of the chiton-wearer, with legs distinctively further apart and the right foot supported on a lower level, may be interpreted as running away from or rushing toward a central event.[39] The two figures must have been conceived according to the different iconographical requirements of the two compositions in which they appeared, which would have affected their structure, poses, the outstretched arms, and the meaning of their gestures.

In trying to reconstruct the original appearance

FIG. 6a

Left corner akroterion from the west side of the temple of the Athenians. Front view. Delos, Archaeological Museum A 4279. Photos: DAI Athens.

FIG. 7a

Right corner akroterion from the west side of the temple of the Athenians. Front view. Delos, Archaeological Museum A 4280. Photos: DAI Athens.

FIG. 6b

Left side of left corner akroterion, figure 6a.

FIG. 7b

Left side of right corner akroterion, figure 7a.

FIG. 8a

Peplos figure. Front. Paris, Musée du Louvre MA 3072. Photos: Giraudon.

FIG. 8b

Right side of peplos figure, figure 8a.

of the two figures we face other problems with respect to their clothing. The waving edge on the left side of the peplos-wearer's waist (fig. 1a) has been interpreted as an overfold,[40] but it is difficult to understand how the open peplos, which reveals her right leg, could have had an overfold. A series of photographs taken by Giraudon before World War II (figs. 8a–b)[41] shows the characteristic radiating folds, indicating that the missing part of the peplos must have been belted. If there had been an overbelted overfold as well, some parts of its edge at least must have appeared floating over the right thigh, and that would have survived under the overlapping mass of the modern torso. This can be observed in almost all running figures wearing an overbelted peplos with an overfold, whether long, as in the case of the Nike from the Athenian Agora (fig. 9),[42] or short, as in the Delos figures (figs. 6a–b, 7a–b) as restored by A. Hermary[43] and the arrangement of the "Aura" in the Athens National Museum (figs. 10a–b).[44] On the other hand, even if the postulated overfold had not been belted over, it should either be visible on the back of the figure, as in the case of the Leda in Boston (see fig. 30b), discussed below, or with its front edge blown up loose, leaving no trace on the lower body, as it does, for example, in the case of the so-called Hebe from the Athenian Agora (fig. 11).[45]

The solution to the enigma of the peplos-wearer's drapery has been forwarded by Brunilde S. Ridgway, who noticed that the remnant of the windblown edge at the waist and the looped folds on the raised thigh are parts of the same garment clearly visible in the old Giraudon photographs (figs. 8a–b).[46] Ridgway nevertheless clung to the idea that there was an overfold, despite the fact that her observation makes the restoration of an overfold highly

FIG. 9
Nike. Athens, Agora Museum S 312. Photo: Agora Excavations.

improbable, in fact virtually impossible because of the very uneven length of the existing material and the way in which it would conflict with the motion of the body in a manner for which no parallel is known. Thus Picard's proposal is shown to be at least partially correct, and the figure should be restored with a kind of chlamys or short mantle spread out on her back like a sail filled with wind.[47] One end of this second garment must have been wrapped around her lowered left arm, which was pressed against the torso, and the other end would have been held up by her raised right hand. The mirror image parallel of the so-called Aura

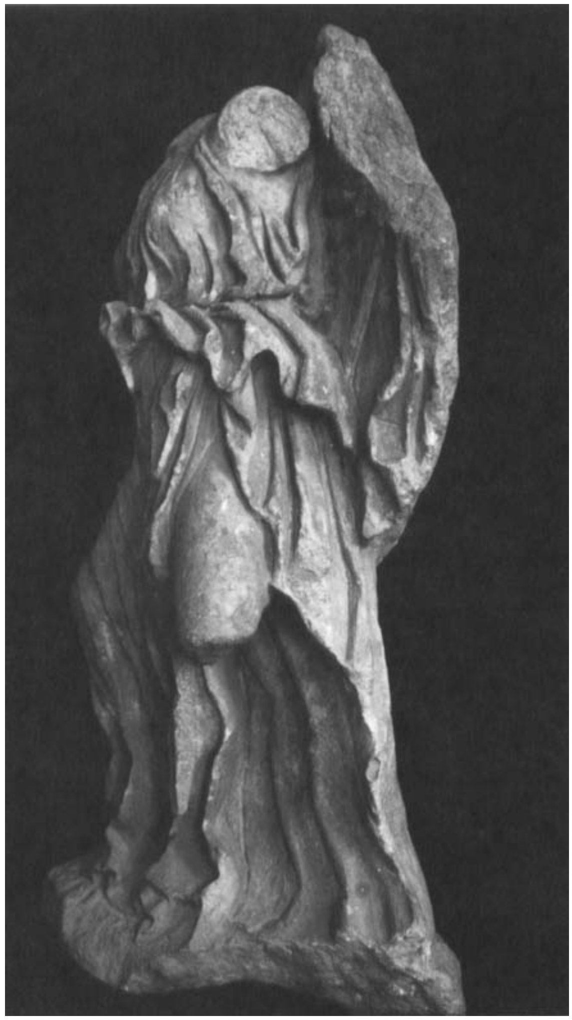


FIG. 10a

"Aura." Front. Athens, National Museum 3043. Photos: DAI Athens.

FIG. 10b

Left side of "Aura," figure 10a.

in Athens (figs. 10a–b) helps us to understand its flow. Still closer is the fragment of another akroterion, in Naples (fig. 12); in fact its stylistic similarity to the Louvre peplos-wearer is so strong that before I accepted Evelyn Harrison's attribution of it to the Ares temple in the Athenian Agora, I had even made an attempt to join the two pieces with the aid of a cast provided by A. de Franciscis.[48] Although my proposed restoration of the peplos-wearer in the Louvre (fig. 13) lays no claim either to artistic quality or exactness, it nevertheless has the advantage of conveying a sense of excitement, in contrast to the solution chosen by the sculptor who restored both the garments and the pose (fig. 1a). The composition that emerges from the new restoration of the peplos-wearer is absolutely different in spirit from that of the chiton-wearer (fig. 2a), presenting yet another argument against the coexistence of the two statues in the same, necessarily symmetrical group of akroteria. The peplos-wearer is indeed an akroterion, but the chiton-wearer is not.

We may now return to the chiton-wearer. The figure faces left (fig. 2a) wearing a very thin sleeveless chiton with a short overfold floating above her breasts, the folds forming a peculiar "arabesque" as a kind of sculptor's signature. The looped folds on the raised thigh are distinct from those of the peplos-wearer.[49] Their composition and function differ, for they belong to a long mantle designed to be held by her upraised right and her lowered left hands. But the back of the statue, roughly sketched and unfinished (fig. 2d), shows that the original intention of the sculptor was never carried through. The chiton folds and the edges of the mantle, defined by the two sharp lines converging below the left shoulder, end abruptly. It is hard to guess the reason for such a drastic alteration, which resulted in the otherwise unknown example of a long heavy mantle suspended in such an unrealistic manner neither from the shoulders nor from the arms. Either the sculptor deliberately changed the composition in the midst of carving, or an unfortunate flaw in the marble forced a change in plan. In any event, it seems probable that the sharp cutting of the mantle belongs to the original carving rather than to a later repair.[50]

FIG. 11

"Hebe." Akroterion from the Temple of Ares. Athens, National Museum 1732 + Agora S 1539. Photo: Agora Excavations.

The differences in the way the two figures are composed would also explain the great difference in style which, as far as I know, has up until now been pointed out, briefly, only by E. Coche de la Ferté, who distinguished "le reflet de deux manières différentes."[51] Otherwise scholars have been unanimous in assuming that the two figures are identical in style, directly linked either to the otherwise elusive personality of Kallimachos[52] or to the Master of the Nereid Monument,[53] or even to a Peloponnesian workshop.[54] While the problems of attribution are irrelevant to this study, the problem of dating is important.

FIG. 12

Torso of a riding nereid. Front. Naples, Museo Nazionale. Photo: DAI Rome.

Without wishing to enter the labyrinth of criteria for determining chronology, I would like to observe that the previously noted relations of both figures to the "Fréjus" Aphrodite (fig. 14),[55] the Athena Nike temple parapet frieze (fig. 15),[56] and the maenad reliefs (fig. 16)[57] point to a date of about 400 B.C. as proposed by F. Hiller[58] and not, as previously supposed, to about 420 B.C.[59] The later date accords well with the current tendency to lower the date of the Bassae frieze even beyond the end of the fifth century.[60] On the other hand, Picard opened up new perspectives by showing that the chiton-wearer is extremely close to the controversially dated Este Aphrodite in Vienna (fig. 17),[61] which Hiller has characterized as "ein sehr gutes Original aus dem beginnenden 4. Jh."[62] Ridgway has recently reemphasized the striking parallels between the two works but thrown doubt on the dating of the Louvre chiton-wearer to Classical times by following an earlier conjecture that the Este Aphrodite is Hellenistic:

Given the differences in costume and rendering of the two figures, is it possible to assume that the woman facing right is a Greek original of the

FIG. 13

Drawing showing how the Louvre peplos-wearer may be reconstructed. Drawing: author.

FIG. 14

"Fréjus" Aphrodite. Paris, Musée du Louvre MA 525. Photo: Hirmer.

late fifth century which was given a counterpart in later (Roman?) times when transported to Rome? In support of this hypothesis note, in the chiton wearer, the very long folds crossing the entire body at a diagonal and the excessive mannerism in the transparent drapery, especially the decorative motif of the neckline.[63]

These conjectures inevitably affect Ridgway's assessment of the Louvre figures and require further analysis. Both the chiton-wearer and the Este Aphrodite do indeed have very long, continuous, razor-sharp folds delineating the anatomy of the body diagonally from the breasts downward, the texture of the thin garment becoming one with the epidermis, but these elements occur in varying degrees of emphasis in almost all of the above-mentioned parallels. They can be traced back through the Fréjus Aphrodite (fig. 14) and the reliefs of the Nike parapet (fig. 15),[64] to the Erechtheum reliefs[65] and the Bassae frieze,[66] and to such important originals of the late rich style as the so-called nereid from the Athenian Agora (fig. 18).[67] The same is true of some other famous creations reflecting the same spirit carried to the limits of its potentialities, such as the Valentini type Aphrodite known only from Roman copies (fig. 19)[68] and the late Classical Aphrodite from the Athenian Agora (fig. 20).[69]

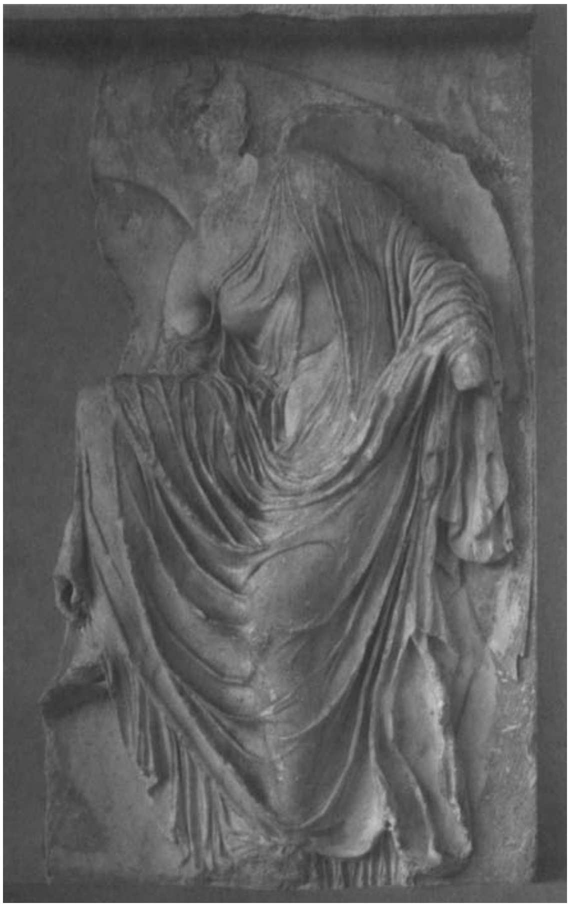


FIG. 15

The Sandal-binder from the Temple of Athena Nike parapet. Athens, Akropolis Museum 973. Photo: DAI Athens.

FIG. 16

Maenad relief. Madrid, Museo del Prado. Photo: Hirmer.

The extreme virtuosity inspiring the manneristic tendencies toward the end of the fifth century B.C. led to the fanlike lines of the folds that frame the exaggeratedly fleshy bodies against rather weakly articulated drapery, as, for instance, in the case of the maenad reliefs (fig. 16), which fortunately have still escaped the hazards of being dated to the late Hellenistic, classicizing, or even Roman periods.[70] The fragmentary, badly weathered torso from the Akropolis of an Aphrodite leaning on a tree (fig. 21) provides evidence for the early date of the Louvre figure as well as for its provenance from an Athenian workshop, since the Akropolis Aphrodite has almost exactly the same system of folds with the same quality and the same idiosyncratic motif of an "arabesque" on the opening of the chiton under the neck.[71] The Akropolis Aphrodite is a further link, connecting the Louvre chiton-wearer to the Este Aphrodite (fig. 17). The latter has been assigned wildly different dates, ranging from the late fifth century B.C. all the way to the Roman period. The situation has recently been summarized by J.-P. Niemeier, who dates the Este Aphrodite in the third quarter of the second century B.C. after an exhaustive theoretical analysis and a series of questionable comparisons, including the fifth-century B.C. Alkamenian Leaning Aphrodite and the second-century B.C. dancer from Pergamon.[72] In judging the work to be an eclectic creation, Niemeier understands the Eros leaning on her shoulder as a reversed repetition of the Skopaic Pothos, believing that the same gradual metamorphosis of an earlier type is also to be seen in the case of the Pergamene Athena with the cross-band aigis.

Each of the scholars who has previously dealt with the Este Aphrodite has advanced his own theory, unsupported by any close parallels or any decisive arguments. It is indeed hard to perceive even a remote echo of the Este Aphrodite in the dancer from Pergamon, an incomprehensible comparison originating with L. Alscher, who attached undue significance to the stance and to the system of drapery folds on the figure.[73] But, supposing that the drapery folds were, after all, relevant, then a comparison with the much closer Leda by Timotheos would be more logical.[74] The Athena from Pergamon must date earlier than the fourth century B.C., according to the evidence provided by a recently discovered relief in Albania.[75] The same is true of the motif of the leaning Eros, which occurs again and again in different media from the early fourth century B.C. onward.[76] The build of the work itself does not permit the various hit-or-miss comparisons put forward by scholars attempting to date it toward the end of the fourth–beginning of the third century B.C. because of the supposed similarities with the Farnese type Herakles[77] or the Silenus with the infant Dionysos.[78] This is also true of the comparison with the Alkamenian Aphrodite in the Gardens, which likewise leans on a support, although her feet are crossed and she has a far more compact structure.[79] The date of the Este Aphrodite is somewhere between the upper limit of the fifth-century B.C. leaning Aphrodite in the Gardens and the lower limit of the late fourth-century B.C. leaning figures. Among these figures by far the closest parallel is the Daphni Aphrodite reproduced on the badly weathered relief of about 400 B.C. dedicated by the son of a certain Theogenes (fig. 22).[80] The stance, the unbroken flow of the himation folds, and the tree trunk serving as a support may rank among the essential resemblances between the two works.

FIG. 17

Este Aphrodite. Vienna, Kunsthistorisches Museum 1192. Photo: Kunsthistorisches Museum.

FIG. 18

"Nereid." Athens, Agora Museum S 182. Photo: Agora Excavations.

The one-dimensional critical approach divorcing the structure from the personal style accounts for the vicissitudes in the history of assessment of the Este Aphrodite. The high quality of the statue may now be better appreciated thanks to the new photographs taken by Ruth Balluff of the cast in the Tübingen University collection (figs. 23a–c). As H. Schrader has already observed, the treatment of the body and its relation to the drapery is in direct contact with the artistic milieu to which we owe the Fréjus Aphrodite type (fig. 14).[81] Nevertheless, the manneristic treatment, overemphasizing the volumes of the body in the midst of the calligraphic handling of the drapery, aiming at an illusion of contrasts in the sharp chiaroscuro, and

FIG. 19

Valentini type Aphrodite. Rome, Palazzo Lazzaroni. Photo: DAI Rome.

FIG. 20

Aphrodite. Athens, Agora Museum S 37. Photo: Agora Excavations.

FIG. 21

Leaning Aphrodite torso. Athens, Akropolis Museum 2861. Photo: DAI Athens.

the general fluidity of the forms has advanced the Este figure further, to a phase more reminiscent of the maenad reliefs (fig. 16).

A comparison of the Este Aphrodite with a hitherto unknown statue from the Libyan Ptolemais (fig. 24) showing the goddess in a similar pose, with a peculiar type of head – presumably a portrait – reveals that the Este Aphrodite is earlier. This extremely important work, undoubtedly from Roman times, is only known to me from a single photograph kindly provided by W. Gauer, from which H. D. Connelly in the Department of Art and Archaeology at Princeton University was able to produce a much clearer print.[82] The calligraphic style of the Libyan Aphrodite comes close to a chilly academicism most noticeable in the conventional way the himation falls along the support. The way in which the end of the material is wrapped around the right leg does, indeed, have some parallels in the early fourth century B.C., as for example on the fragmentary Aphrodite in the Athenian Agora (fig. 20).[83] It would be difficult, nevertheless, not to regard the coiffure with the hair done up in a bow as eclectic,[84] especially combined with the motif of the himation falling from the head, again eclectically repeating another problematic version of the leaning goddess.[85] The Aphrodite of Ptolemais is certainly related to the fragment of what must have been a leaning figure in Boston, which might indeed derive from a second copy of the same eclectic creation (fig. 25).[86] The contrast with the Este Aphrodite makes it clear, in my view, that the latter statue is by far the earlier work. There is also an obvious iconographical and stylistical interdependence between the Este Aphrodite and the Weimar-Venice Asklepios, whose head type has recently been identified in Argos and correctly dated by J. Marcadé to the first quarter of the fourth century B.C. (fig 26).[87]

FIG. 22

Drawing of Aphrodite on a votive relief from Daphne. Athens, National Museum 1601 (from *AntPl* 8 [1968], p. 24, fig. 1).

The date of the Este Aphrodite and the fact that she comes from the same pedimental composition as the Louvre chiton-wearer accounts for the otherwise inexplicable two-dimensional treatment, especially noticeable in her side views (fig. 23b) as well as the sketchy rendering of the back (fig. 23c). Last-minute adjustments in the pediment apparently necessitated the recutting of the protruding masses of the tree support. Similar recutting is seen on other pedimental figures: when their dimensions had not been precisely calculated, adjustments were necessary after they were mounted in the pediment.[88] As noted above, the Louvre figure shows the same technical treatment, and because of her position in the pediment, she shows the same degree of sketchy modeling on the back (fig. 2d), in contrast to the sophisticated workmanship of the front view (fig. 2a). If it were possible to trace the Este Aphrodite back to Rome, then we would have additional evidence for supporting its connection with the Louvre chiton-wearer; but my efforts to discover how the statue entered the Este collection before going

FIG. 23a

Este Aphrodite. Front. Photos by Ruth Balluff from a cast in Tübingen, Archäologisches Institut.

FIG. 23b

Left side of cast of Este Aphrodite, figure 23a.

FIG. 23c

Back view of cast of Este Aphrodite, figure 23a.

FIG. 24

Aphrodite leaning on a pillar. From Ptolemais, Libya. Libya, Ptolemais Museum. Photo: W. Gauer.

to Vienna have proved fruitless.[89]

In the Villa Albani, however, there is another sculpture, apparently found in Rome, which I have not seen with my own eyes but which may belong to the same set of pedimental figures.[90] Its importance had already been stressed by Walter Amelung, but after C. Watzinger's discussion in 1913 it was forgotten, probably because of the appalling restoration with a large and ugly Roman head (fig. 27a).[91] It represents a figure wearing a chiton that has been heavily restored in the entire upper part of the body in a line following the running folds of the garment between the breasts. Both arms and the lower part of the right leg have also been restored. Yet the original appearance has been rendered with a certain degree of plausibility, thanks to the surviving *Standmotiv* and the preserved parts of the mantle, which fix the movement of the arms and the meaning of the gesture. A direct dependence of the Albani figure on the Fréjus Aphrodite (fig. 14) is certainly obvious,[92] but the modeling, the playful linear treatment of the garments, the fleshy structure of the body, and the stance all recall the general sculptural concept of the Este Aphrodite. The same is true for the proportions of the two works,[93] although the Classical date of the Albani figure needs to be investigated more thoroughly.[94] The relationship of the two works emerges more clearly in a new print of the old photograph illustrating the partial removal of the restorations to the statue in the Villa Albani in an attempt to recreate its original appearance (fig. 27b).[95]

FIG. 25

Torso of a leaning figure. Boston, Museum of Fine Arts 01.8203. Photo: Museum of Fine Arts.

FIG. 26

Asklepios. Argos Archaeological Museum 350 + 377 + 296. Photo: L'Ecole française d'Athènes.

There is only one subject that would account for the presence of the Louvre chiton-wearer and the Albani and Este Aphrodites in the same composition: the myth of the persuasion of Helen as an intermediate incident between the Judgment of Paris and the outbreak of the Trojan War.[96] In that case the Vienna figure leaning on the tree could be seen as the Laconian heroine, who evolved from an early deity of vegetation, being influenced by Eros; the way in which the Albani figure holds her himation in a gesture of unveiling is typical for the goddess of love and would identify her as Aphrodite.[97] The Louvre chiton-wearer together with a non-existing or still unidentified counterpart on the opposite half of the pediment would represent one of Helen's companions, if not one of Aphrodite's retinue, hastening to find out what is going to happen.[98]

This is not the place to continue the tiring quest for further scattered sculptures that could be candidates for the pedimental composition under consideration. It is, however, necessary to return to the Copenhagen kitharist (figs. 4a–d) since I have sought to replace his old identification as Apollo with a new one: Paris. Seen from the side (figs. 4c–d) the statue does bear a certain resemblance both to the running girl in the Louvre (figs. 2b–c) and to the leaning figure in

FIG. 27a

Aphrodite. Rome, Villa Albani 4 (from *EA* 1106).

FIG. 27b

Aphrodite, figure 27a, with restorations partly removed. Photo: Charles Passela.

Vienna (fig. 17) as well as to the Albani Aphrodite (figs. 27a–b). But it is hard to establish whether this relationship reflects some general tendencies of a certain period or a more direct stylistic affinity. In the workmanship of the back, the Copenhagen figure is totally different from and much more advanced than the unfinished Louvre and Vienna figures, thus implying another context, although one cannot exclude the possibility of different stages of execution as well as different hands in the same pedimental composition. Yet it is more difficult to relate the Copenhagen figure to the others, not only because of its much larger size (it is 1.26 m high) but also because the head, right arm, and part of the left foot were separately worked and attached, indicating a totally different technical procedure.

If the problem of the Copenhagen kitharist is better left open, the same does not hold true for two other sculptures that have previously been suggested as belonging to the ensemble of the Louvre figures and the Apollo temple at Bassae. The so-called Aura from the Palatine in the Museo Nazionale Romano (figs. 28a–b)[99] must definitely be rejected as a possible candidate on technical grounds alone, not to mention that she has tentatively been assigned to the temple of Nemesis at Rhamnous[100] and also suggested as a counterpart to the Agora Nike (fig. 9)[101] and even attributed to a South Italian workshop.[102] The figure was undoubtedly an akroterion, but the impressive flow of her rich garments in back (fig. 28b) has a three-dimensional force quite different from the restrained modeling of both the Louvre peplos-wearer

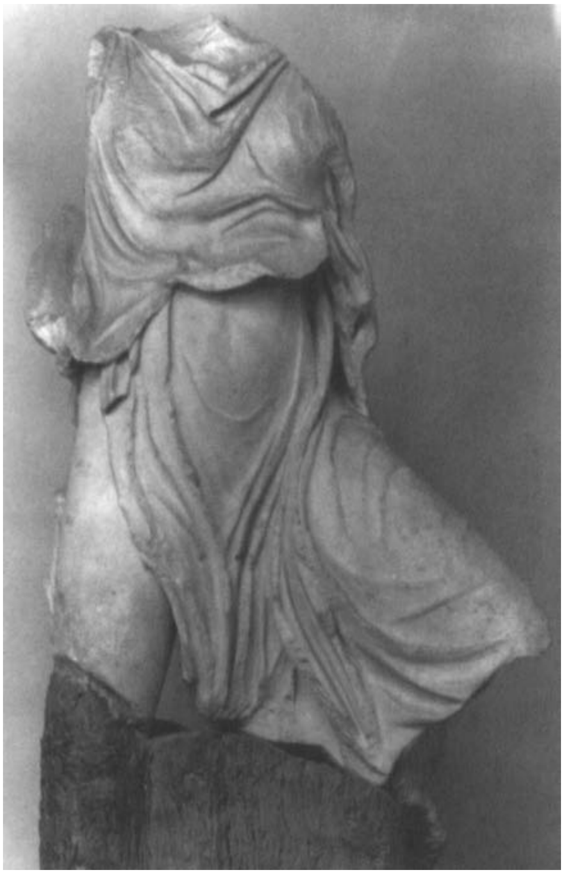


FIG. 28a

The Palatine "Aura." Front. Rome, Museo Nazionale Romano 124.697. Photos: DAI Rome.

FIG. 28b

Back of the Palatine "Aura," figure 28a.

akroterion and the pedimental chiton-wearer.

Even more complicated is the case of another statue which, having been auctioned at Sotheby's in 1937, was added to the group by Picard before vanishing into a private collection (fig. 29a).[103] Its presence in Rome in the mid-sixteenth century was revealed by P. Pray Bober and N. W. Canedy thanks to a sketch by Girolamo da Carpi (fig. 29b),[104] while E. Paribeni had already identified it with the figure restored as "Diana" at the Palazzo Marconi by means of the still valuable work of F. de Clarac (fig. 29c).[105] Judging from the only published photograph, I must confess that it is hard to decide whether it represents, as I think, a reworked Greek original or, as has been generally supposed, a Roman copy.[106] It is also difficult to judge whether the figure was originally intended as a pedimental figure or as an akroterion. Its stylistic affinities to the pedimental figures indicate that it, too, was designed for a pediment, but on the other hand its movement is so close to the pose of the chiton-wearer in the Louvre that it seems impossible that both have been present in the same pediment, for that would have been boringly repetitive. The similarity would, of course, not speak against a provenance from the second pediment of the same temple, to which nothing can be safely assigned, were it not for the fact that the Sotheby akroterion's preserved height of 1.34 m excludes the pedimental origin a

FIG. 29a

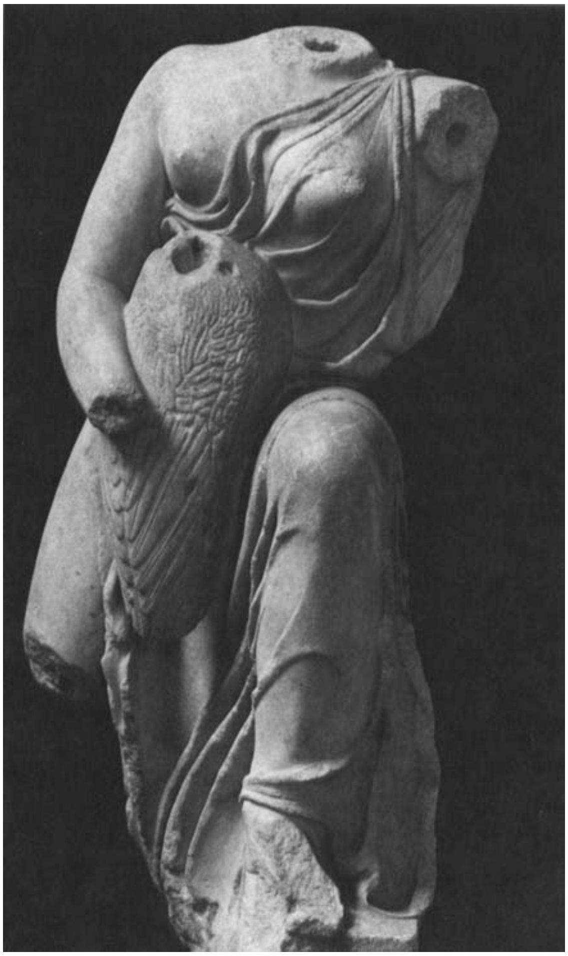
The Sotheby's akroterion. Private collection (from Picard, fig. 7).

FIG. 29b

The Sotheby's akroterion, figure 29a. Drawing by Girolamo da Carpi (from Pray Bober and Canedy, no. R86, pl. 11).

FIG. 29c

The Sotheby's akroterion, restored as Diana. Rome, Palazzo Marconi (from Clarac, no. 1230, pl. 574).



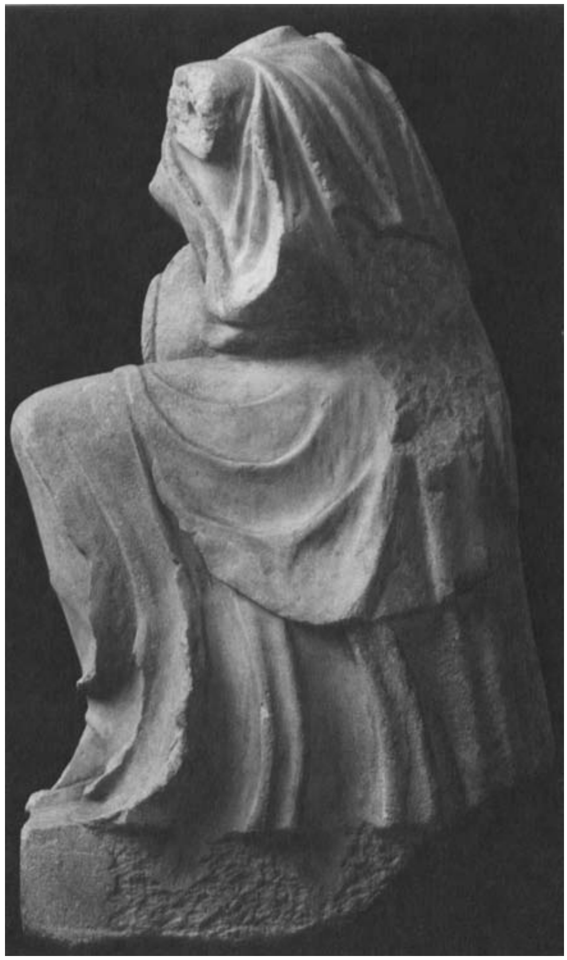


FIG. 30a

Leda. Front. Boston, Museum of Fine Arts 04.14. Photos: Museum of Fine Arts.

FIG. 30b

Back view of Leda, figure 30a.

priori.[107] The same holds true for the differences in style with the peplos-wearer in the Louvre. These differences stand in the way of assigning the Sotheby figure to the same akroterion composition as the Louvre figure, but there is no reason why the Sotheby figure may not have belonged to the group of akroteria crowning the other end of the same temple.

Turning now to search for sculpture that would complete the akroteria composition of which the Louvre peplos-wearer was part, I will end by discussing briefly the famous Leda in Boston (figs. 30a–b).[108] Before traveling to the United States this extremely important piece of late fifth-century B.C. Attic sculpture[109] had formed part of the Farnese collection in the renowned Palazzo at Caprarola near Rome.[110] The stylistic connections between the Leda and the Louvre peplos-wearer have been indicated by Lippold[111] and elaborated on by Ridgway, who suggested that the Leda was a lateral akroterion with a corresponding group in the opposite corner.[112] In view of the fact that all three akroteria in the same composition must necessarily form a tightly bound unity with a coherent theme, I would prefer to see the Leda as the focal point on top of the pediment, her centripetal structure harmonizing with the restored movement of the peplos-wearer in the Louvre (fig. 13). The reworked sections on the backs of the two figures (figs. 1d, 30b) as well as their heights (Leda 0.885 m, peplos-wearer 1.13 m) make their relationship more obvious, permitting the hypothesis that in the sixteenth century they both decorated a fountain in the Farnese gardens where, as we know, Leda had stood.

It thus seems probable that the common origin of the whole group of sculptures under discussion was at least suspected in the post-Renaissance period, though there is little information available for the history of some of them. Mary Comstock and Cornelius Vermeule have tentatively attributed the Boston Leda to the temple of Nemesis at Rhamnous because the subject is appropriate.[113] It is equally suitable for the conjectured subject of the pedimental sculptures under discussion. This idea is, indeed, attractive and would fit the interpretation I had previously proposed for the akroterion group from Rhamnous as representing the abduction of Helen by Theseus.[114] Furthermore, there are some slight stylistic similarities between the two works, such as the deep concave scoops at the end of the folds[115] and the workmanship of the sandals. The fragmentary state of the Rhamnous group as well as its estimated height prevent any further comparisons, and the preserved architecture of the temple, providing no evidence for pedimental sculpture, does not seem to support the attribution.[116] On the other hand, the same thematic cycles would have been equally appropriate to any temple of Aphrodite, either in Athens itself or in the vicinity.

Well aware of how little progress I have made in answering the questions concerning this much-studied group of sculptures, I close with the hope that my investigations will inspire others to continue efforts in this direction.

Benaki Museum
ATHENS

Notes

Boardman:
J. Boardman, *Greek Sculpture: The Classical Period* (London, 1985).

Danner:
P. Danner, *Griechische Akrotere der archaischen und klassischen Zeit*, RdA, suppl. 5 (1985).

Delivorrias:
A. Delivorrias, *Attische Giebelskulpturen und Akrotere des 5. Jhs.* (Tübingen, 1974).

Gulaki:
A. Gulaki, *Klassische und klassizistische Nikedarstellungen* (Bonn, 1981).

Harrison:
E. B. Harrison, in *Proceedings of the Twelfth International Congress for Classical Archaeology*, vol. 3 (Athens, 1988), pp. 99ff.

Hofkes-Brukker:
C. Hofkes-Brukker, *BABesch* 40 (1965), pp. 51ff.

Lippold:
G. Lippold, *Die griechische Plastik: Handbuch der Archaeologie*, vol. 3, part 1 (Munich, 1950).

Picard:
C. Picard, *MonPiot* 39 (1943), pp. 49ff.

Ridgway:
B. S. Ridgway, *Fifth Century Styles in Greek Sculpture* (Princeton, 1981).

Vierneisel-Schlörb:
B. Vierneisel-Schlörb, *Glyptothek München: Katalogue der Skulpturen*, vol. 2 (Munich, 1979).

1 The material under discussion was collected years ago in Tübingen for an originally planned but finally not included last chapter of my dissertation on the pedimental sculptures and akroteria of Classical temples, many conclusions of which I would today regard with a more critical eye. I owe the present reworking of the subject to a three-months' stay at the Institute for Advanced Study at Princeton and to the inspiring atmosphere created there by Dorothy and Homer Thompson. Warm thanks are due to Mary Sturgeon, who read the text and made valuable suggestions, and to the many friends who helped in different ways with obtaining information and photographs: B. Andreae, R. Baluff, E. Bielefeld, M. Brouskari, J. McK. Camp, W. A. P. Childs, H. D. Connelly, B. Cook, P. Devambez, J. Diamant, A. de Franciscis, W. Fuchs, L. Fusco, W. Gauer, I. Kocollari, H. Kyrieleis, N. Lazarides, C. Mauzey, H. Meyer, M. Moltesen, A. Pasquier, O. Picard, C. A. Picon, K. Stähler, I. Triandi, S. Triandis, and C. C. Vermeule. Finally I wish to thank Judith Binder not only for revising my English but also for helping me clear up many obscure points.

In order to save space, the introductory part of my talk at the symposium has been omitted.

2 Louvre MA 3072 (figs. 1a–d) and MA 3516 (figs. 2a–d): Picard, pp. 49ff.

3 F. Aurelio and A. Visconti, *Indicazione delle sculture e della galleria de' quadri esistenti nella Villa Miollis al Quirinale* (Rome, 1814), p. 44; Picard, pp. 56f., fig. 3.

4 F. Matz and F. von Duhn, *Antike Bildwerke in Rom*, vol. 1 (Leipzig, 1881), pp. 250f., nos. 932–933.

5 S. Reinach, *Répertoire de la statuaire grecque et romaine*, vol. 2, part 1 (Paris, 1897), p. 384, no. 8 and p. 385, no. 1. According to Picard, p. 57, these drawings were copied "assez inexactement" from Visconti's drawing (note 3) after the two figures had already been removed from the Villa Lante.

6 Lippold, p. 209, n. 2; S. Reinach, *L'Album de Pierre Jacques, sculpteur de Reims dessiné à Rome de 1572 à 1577* (Paris, 1902), p. 127, pl. 50. Ridgway (p. 64, n. 30) credits C. A. Picon with recognizing the statue in the drawing, reproduced here after a photograph taken by H. D. Connelly.

7 According to Picard, p. 57, the restoration of the peplos-figure must be earlier than 1814, when the catalogue of the Miollis collection (note 3) was published.

8 *AJA* 60 (1956), p. 401, n. 3.

9 Ny Carlsberg Glyptotek 497: Hofkes-Brukker, pp. 51ff., figs. 1–5, 21–24, with bibl. For the interpretation of the figure as an akroterion, see A. Furtwängler, *SBMünchen*, 1902, p. 443; G. Lippold, *Antike Skulpturen der Glyptothek Ny Carlsberg* (Leipzig, 1924), p. 13; S. Karouzou, *AthMitt* 89 (1974), p. 169.

10 Hofkes-Brukker, p. 57.

11 Picard, pp. 73f., 76.

12 Cf. B. Schlörb, *Untersuchungen zur Bildhauergeneration nach Phidias* (Waldsassen, 1964), p. 49: "Da die Figuren keine Flügel haben, handelt es sich wahrscheinlich nicht um Niken, sondern um Nymphen, die von Apollon verfolgt werden."

13 Compare, e.g., J. Charbonneaux, *La Sculpture grecque et romaine au Musée du Louvre* (Paris, 1963), p. 28: "Ces deux statues représentent sans doute des Néréides ou des Nymphes."

14 Matz and von Duhn (note 4) in a chapter about "Weibliche Personificationen in lebhafter Bewegung."

15 Delivorrias, pp. 5, 38f., elaborating on U. Wester's well-thought-out observation ("Die Akroterfiguren des Tempels der Athener auf Delos," Ph.D. diss., Heidelberg, 1969, p. 99, no. 91).

16 Cf. K. Stähler's arguments starting with his interpretation of the riding akroterion figures of Sorrento: "Klassische Akrotere," in *Pro Arte Antiqua: Festschrift für H. Kenner*, vol. 2 (1985), p. 328. One of these two figures has recently been interpreted as perhaps a dedication to Artemis or more probably to Aphrodite: Ridgway, p. 117, fig. 91; *LIMC*, vol. 2, p. 674, no. 697, s.v. "Artemis." Cf. the "documenti di dubbia interpretazione" listed by F. Canciani in *LIMC*, vol. 3, p. 53, nos. 10–17, s.v. "Aurai," and P. Danner, *Röm Hist Mitt* 30 (1988), p. 33, figs. 23–24.

17 In the past I unhesitatingly accepted the idea of a unified representation with Apollo, Artemis, and Leto: Delivorrias, p. 38. When Ridgway analyzed the Louvre statues, she expressed doubt about the unity of the three figures only in the index, where she listed the Apollo as "Bassae acroterion?" (Ridgway, p. 251). In other words, the absence of any mention of the "Apollo" in works where the Louvre figures are discussed indicates that the authors had reservations about the theory, e.g., E. Kostoglou-Despini, Προβλήματα τῆς παριανῆς πλαστικῆς τοῦ 5ου αἰώνα π.Χ (Thessaloniki, 1979), pp. 144f.; E. Raftopoulou, *BCH*, Suppl. 6 (1980), pp. 123ff., figs. 9–11; Gulaki, pp. 110f., figs. 65–66; A.-I. Triandi, Ὁ γλυπτὸς διάκοσμος τοῦ ναοῦ στὸ Μάγι τῆς Ἠλείας (Thessaloniki, 1985), pp. 129ff., 138. Yet another argument against the akroterion interpretation is the lack of weathering: Danner, p. 93, A36.

18 The only example in Attica, as far as I know, is a stele in the Yeroulanos collection at Trachones, an isolated case: S. Karouzou, *AthMitt* 89 (1974), pp. 167f., pls. 68–70; A. G. Mandis, Προβλήματα τῆς εἰκονογραφίας τῶν ἱερειῶν καὶ τῶν ἱερέων στὴν ἀρχαία ἑλληνικὴ τέχνη (Thessaloniki, 1983), p. 115, pl. 38a. The indication of sex on the base in the National Archaeological Museum (ibid., p. 104, no. 4) and on other works is much more discreet.

19 Compare, with examples, G. Bakalakis, *AthMitt* 37 (1962), pp. 197ff., esp. pp. 199f., with Beilage 55; W. A. P. Childs, *OpusRom* 9 (1973), pp. 105ff., esp. p. 106.

20 See H. Thiersch, *Ependytes und Ephod: Gottesbild und Priesterkleid in alten Vorderasien* (Stuttgart and Berlin, 1936).

21 There is but one example of Apollo wearing the ependytes, and it is rather late: Hofkes-Brukker, pp. 52f., n. 13. In *LIMC*, vol. 2, p. 203, no. 136, s.v. "Apollon," the Copenhagen figure has been routinely listed under Apollo in spite of the fact that none of the undoubted statuary Apollo types wears the ependytes: the Barberini type (ibid., no. 146), the Sabriano-Corsini type (no. 147), the Apollo by Euphranor (no. 145), Apollo Musagetes (no. 135), the Vatican-Santa Barbara type (no. 146), and the Geneva type (no. 151).

22 K. M. Türr, *Eine Musengruppe hadrianischer Zeit* (Berlin, 1971), p. 60, n. 93. Cf. the views (untenable in my opinion) of other scholars: F. Poulsen, *Catalogue of the Ancient Sculpture in the Ny Carlsberg Glyptotek* (Copenhagen, 1951), pp. 70f., no. 63; Gulaki, p. 183, figs. 139, 140, 142. Cf. E. Simon in *LIMC*, vol. 2, p. 375, no. 42, s.v. "Apollon/Apollo."

23 Cf. L. B. Ghali-Kahil, *Les enlèvements et le retour d'Hélène dans les textes et les documents figurés* (Paris, 1955), pp. 128ff., esp. p. 131: "A son charme exotique, le séducteur alliait un luxe non moins fascinant" and p. 138: "Cependant, deux traits nouveaux sont mis en relief: d'une part la beauté de Paris, son attrait, et de l'autre son allure de riche prince oriental." Among numerous related verses of Euripides, cf. *IA* ll. 71–76:

ἐλθὼν δ' ἐκ φρυγῶν ὁ τὰς θεὰς
κρίνων ὅδ', ὡς ὁ μῦθος 'Αργείων ἔχει,
Λακεδαίμον', ἀνθηρὸς μὲν εἱμάτων στολῇ
χρυσῷ δὲ λαμπρός, βαρβάρῳ χλιδήματι,
ἐρῶν ἐρῶσαν ᾤχετ' ἐξαναρπάσας
'Ελένην πρὸς Ἴδης βούσταθμα

and *Tro.*, ll. 991–992:

ὃν εἰσιδοῦσα βαρβάροις ἐσθήμασι
χρυσῷ τε λαμπρὸν ἐξεμαργώθης φρένας.

In addition to the examples of Paris wearing an ependytes collected by L. Gahli-Kahil, see also *LIMC*, vol. 1, p. 449, no. 12; p. 506, nos. 47 and 50; p. 511, no. 65, s.v. "Alexandros."

24 Paris is associated with a kithara since the time of Homer; cf. *Il.*, III.54–55:

οὐκ ἄν τοι χραίσμῃ κίθαρις τά τε δῶρ' 'Αφροδίτης
ἥ τε κόμη τό τε εἶδος, ὅτ' ἐν κονίησι μιγείης

Cf. *LIMC*, vol. 1, p. 499, nos. 9–11, s.v. "Alexandros." This explains the musical ecstasy that Hofkes-Brukker, p. 54, sees in the Copenhagen figure, together with the feeling that Apollo has just arrived from a journey over the ocean; cf. K. A. Pfeiff, *Apollon: Die Wandlung seines Bildes in der griechischen Kunst* (Frankfurt am Main, 1943), pp. 112f.: "Das Rauschen des Gewandes ist vielmehr Ausdruck innerer, musikalischer Erregung, die im Wurf der Falten ihr Tempo, in ihrer Ordnung ihre Takte, und ihrem Fluss ihre Melodien erklingen lässt." On the other hand, the sexuality of the figure recalls Euripides, particularly the chorus of satyrs in *Cyc.*, ll. 181–186, referring to Helen:

ἐπεί γε πολλοῖς ἥδεται γαμουμένη;
τὴν προδότιν, ἣ τοὺς θυλάκους τοὺς ποικίλους
περὶ τοῖν σκελοῖν ἰδοῦσα καὶ τὸν χρύσεον
κλῳὸν φοροῦντα περὶ μέσον τὸν αὐχένα
ἐξεπτοήθη, Μενέλεων, ἀνθρώπιον
λῷστον, λιποῦσα

25 *AJA* 72 (1968), p. 207; F. A. Cooper, *The Temple of Apollo at Bassai: A Preliminary Study* (New York and London, 1978), pp. 127ff., figs. 35–40. I am entirely in agreement with Cooper's statement, p. 129, that "the treatment of Louvre 3516 is decidedly different than any figure in the Bassai frieze," but I disagree with his view that a temple could have figured akroteria on one side and floral elements and human figures on the other. For mixed compositions, see A. Delivorrias, *Parthenon-Kongress, Basel* (Mainz, 1984), pp. 289–292. On the composition of the Bassai akroteria, see also Danner, p. 14, nos. 79, 95.

26 Ch. Hofkes-Brukker and A. Mallwitz, *Der Bassai Fries* (Munich, 1975), p. 166 n. 208 (to p. 129). U. Liepmann does not even mention the two Louvre sculptures in her important work, *Das Datierungsproblem und die Kompositionsgesetze am Fries des Apollontempels zu Bassae-Phigalia* (Hannover, 1970).

27 *JSav*, 1909, p. 423.

28 *AJA* 47 (1943), p. 17; *CP*, 1944, pp. 48f. The same views had previously appeared in *TEL: Encyclopédie Photographique de l'Art*, vol. 3 (Paris, 1938), p. 177. For the opposite view, see W. B. Dinsmoor, *AJA* 47 (1943), pp. 19ff., and Hofkes-Brukker, p. 51, n. 1.

29 Delivorrias, p. 195, referring to the akroteria of the west side of the temple of Asklepios in Epidauros; cf. Stähler (note 16) in connection with the Sorrento

akroteria. The problem has been recently reexamined by Danner, pp. 56f., and Danner (note 16), p. 33, figs. 23–24.

30 In distinction to my earlier stand when I supported the consensus of opinion: Delivorrias, pp. 92f.; Wester (note 15), pp. 118f.; E. Langlotz, *Die Kunst der Westgriechen* (Munich, 1963), pls. 122–123; W. Fuchs, *Die Skulptur der Griechen* (Munich, 1969), figs. 393–394; S. Lattimore, *The Marine Thiasos in Greek Sculpture* (Los Angeles, 1976), p. 14, pl. III, fig. 3; *LIMC*, vol. 3, pp. 570f., no. 24, s.v. "Dioskouroi" (A. Hermary); A. Delivorrias, in *Greece and The Sea: Catalogue of an Exhibition in Amsterdam, 1987* (Athens, 1987), p. 46, no. 15. G. Foti, *Klearchos* 21–22 (1964), pp. 21ff., interprets the two figures as pedimental; cf. Ridgway, p. 60; Danner (note 16), pp. 31f., figs. 21–22, pp. 34f., fig. 25.

31 Proposed by Delivorrias, pp. 125ff., pls. 46–53, folding plate 2, following up a suggestion made by E. B. Harrison; compare, however, the photographs showing the arrangement she now prefers: Harrison, p. 104, pl. 20.1. In the meantime the two main pieces of the fragmentary left riding figure have been joined: *Deltion* 29, part B1 (1973–1974), p. 2, pl. 6a; for the upper torso of the right riding figure in Naples, see now W. Fuchs, *Boreas* 2 (1979), pp. 59f., pls. 3–5. See also L. Beschi, *ASAtene* 50–51, n.s. 34–35 (1972–1973), pp. 488ff.; Lattimore (note 30), pp 50f., pls. XVI–XVII; Boardman, p. 148, fig. 119; Danner, p. 22, no. 142, pp. 28f., no. 172, pl. 30.

32 Naples, Museo Nazionale 145070, 145080: E. Bielefeld, *AntPl* 9 (1969), pp. 47ff., pls. 25–36; *RömMitt* 76 (1969), pp. 93ff. with the correct arrangement, apart from the question of judgments about the style and the attribution: cf. D. Willers, *Gnomon* 47 (1975), p. 503; Lattimore (note 30), pp. 51ff., pls. XVIII–XIX, where they are shown posed centrifugally and understood as "eclectic creations of the first century B.C."; Vierneisel-Schlörb, pp. 212, n. 21, 401, 403, n. 24; Delivorrias (note 30), pp. 48f., no. XVII: wrongly illustrated but interpreted as being from Magna Graecia; cf. Danner, p. 32, no. 256, pl. 31.

33 Delivorrias, p. 195; see, contra, N. Yalouris, in H. Kyrieleis, ed., *Archaische und klassische griechische Plastik*, Akten des Internationalen Kolloquiums in Athen, vol. 2 (Mainz, 1986), p. 180, Beilage 4a. Cf. Danner, pp. 29f., no. 174, pl. 32.

34 Delos Archaeological Museum A 4279 (here figs. 6a–b) and A 4280 (here figs. 7a–b): Wester (note 15), pp. 22ff.; Gulaki, p. 79, figs. 72–73; Ridgway, p. 61; A. Hermary, *Délos* 34 (1984), pp. 25ff., pls. XII–XIII, with a restored drawing of the west pediment, pl. XXI; Danner, p. 27, no. 163, pl. 29.

35 Compare, e.g., the so-called Aurai in the Lateran, Museo Gregoriano Profano 15046, 15047, from Palestrina: *AA*, 1973, pp. 642f., figs. 84–85; G. Daltrop, *Bollettino dei Monumenti, Musei e Gallerie Pontificie*, vol. 1, part 3 (Vatican City, 1979), pp. 46f., figs. 56–57; L. Guerrini, *Quaderni di Archeologia della Libia* 10 (1979), pp. 15ff., figs. 3–5, 7–10; Gulaki, pp. 234ff., figs. 216–218; Delivorrias (note 25), no. 25.

36 E. La Rocca, *Amazzonomachia: Le sculture frontonali del tempio di Apollo Sosiano* (Rome, 1985); cf. M. Pape, *Griechische Kunstwerke aus Kriegsbeute und ihre öffentliche Aufstellung in Rom* (Hamburg, 1975), and E. Paribeni, in *Atti B. Conveg. Stud. Magna Grecia 1968* (Taranto, 1969) , pp. 83ff. As K. Stähler has pointed out, a more thorough investigation would lengthen the list: *Boreas* 6 (1983), pp. 77f., n. 15.

37 Picard, p. 55.

38 Hofkes-Brukker, p. 51.

39 According to Picard, p. 55, the "mouvement d'ascension," which follows "la montée des lignes du fronton, au rampart du geison," is a "particularité qui suffirait aussi à exclure l'hypothèse d'enaietia, de statues tympanales." This observation is true only in the case of the peplophoros.

40 Picard, p. 55; Hofkes-Brukker, p. 56.

41 Giraudon neg. 26734 (1916) = our figure 8a; neg. 29145 (1929) = our figure 8b.

42 Agora S 312: Delivorrias, pp. 124f., pls. 43c–d, 45 with the attribution to the Ares temple and bibl. Cf. Boardman, p. 148, fig. 118; contra Gulaki, pp. 63ff., 67, figs. 23–25; Ridgway, pp. 62f., fig. 37: "probably from the Stoa of Zeus" following the first publication; but see E. B. Harrison, *AJA* 65 (1961), p. 190. As Judith Binder informs me, Harrison now suggests that this figure may be a dedication, perhaps by Konon, which stood on a high column or support; for the early fourth-century B.C. date, see Harrison, p. 104, pl. 19, no. 5. Cf. Danner, p. 17, no. 105, pl. 10.

43 A. Hermary, *Délos* 34 (1984), pls. XII–XIII.

44 National Museum 3043: Delivorrias, pp. 191f., possibly a replacement for an Erechtheion akroterion made in Roman times, contrary to A. Linfert, *AA*, 1968, pp. 427ff., who judges the figure to be an original akroterion from the temple of Athena Nike. Vierneisel-Schlörb, p. 403, n. 15, and Ridgway, pp. 61f., agree with my view that the figure dates to the Roman period but maintain that it belongs on the temple of Athena Nike. According to Gulaki, p. 110, fig. 64, the cutting away at the back indicates the pedimental origin of the figure, but she does not commit herself on the problem of the date. Cf. Danner, p. 92, A27.

45 National Museum 1732 + Agora S 1539: Delivorrias, pp. 122f., pls. 39–40 with bibl.; Gulaki, figs. 79–80; Ridgway, p. 62, figs. 33–36; Harrison, p. 24, pl. 20, 3, with a date of around 390 B.C. See contra, Danner, p. 26, no. 158.

46 Ridgway, p. 63.

47 Picard, pp. 54f.; contra, Hofkes-Brukker, p. 56, n. 33.

48 See note 31. Stelios Triandis, the well-known sculptor in the National Museum, carried out the test for the join, after which the cast was turned over to the Agora Museum for the purposes of further study.

49 As noted by Ridgway, p. 63.

50 The restorations in Jacques's drawing (our figure 3) apparently derive from an attempt to reconcile the discrepancies between the movement of the body and the arms on the one hand and the arrangement of the himation on the other; for an example of a himation kept up without being held, cf. the Nike "fleeing toward the right," R. Carpenter, *The Sculpture of the Nike Temple Parapet* (Cambridge, Mass., 1929), pp. 22f., pl. VII; M. Brouskari, *The Acropolis Museum: A Descriptive Catalogue* (Athens, 1974), pp. 171f., Akr. 972 and 2680, fig. 342.

51 E. Coche de la Ferté, *La sculpture grecque et romaine du Musée du Louvre* (Paris, 1951), p. 20.

52 Picard, pp. 51ff., 65, and passim: by the master who designed the Centauromachy frieze at Bassae and the maenad reliefs (see note 57, our figure 16); Schlörb (note 12), p. 49: "Werkstattarbeiten begabter Schüler vom [Bassae] Fries"; Hofkes-Brukker, pp. 68ff.: "Frühwerk des Kallimachos, aus der Periode, als er sicher noch an den Stil des Paionios anlehnte."

53 Lippold, p. 209.

54 Certain scholars who have disassociated the Copenhagen "Apollo" from the Louvre figures (see note 17) still persist in seeing a stylistic resemblance with the Bassae reliefs.

55 Louvre MA 525: on the type, see *LIMC*, vol. 2, pp. 33ff., nos. 225–240, s.v. "Aphrodite." It is difficult for me to follow the argumentation presented in the recent publication of the Thessalonike copy, whereby the prototype is dated before 421 B.C. and the type identified as Aphrodite in the Gardens by Alkamenes: M. Andronikos, *ArchEph*, 1985, pp. 1ff., pls. 1–3. Compare the thoughtful observations made by Ridgway, pp. 198ff.

56 Akropolis Museum 973: Brouskari (note 50), pp. 168f., fig. 333. On the Nike temple parapet, see G. I. Despinis, Συμβολή στή μελέτη τοῦ ἔργου τοῦ Ἀγοράκριτου (Athens, 1971), pp. 170ff.; Ridgway, pp. 96ff. For the dating of the Nike parapet reliefs in several phases beginning before 413 B.C. until around 390 B.C., see Harrison, pp. 103ff.

57 Madrid, Museo del Prado: Fuchs (note 30), pp. 521ff., figs. 610–613; idem, *Die Vorbilder der neuattischen Reliefs* (Berlin, 1959), pp. 72ff. and 89, fig. 1, deriving the whole series from the base of a choregic monument dedicated by Euripides on the occasion of the performance of the *Bacchae* in 406 B.C.; cf. Schlörb (note 12), p. 50; Ridgway, pp. 210ff., figs. 134–135, with R. Carpenter's attribution to "a tall pedestal over which stood the over-lifesize chryselephantine statue made by Alkamenes for the temple of Dionysos in Athens"; Boardman, figs. 243a–b.

58 F. Hiller, *Formgeschichtliche Untersuchungen zur griechischen Statue des späten 5. Jhr. v. Chr.* (Mainz, 1971), p. 69.

59 See the summing up of earlier views, Lippold, p. 201: "Mit der Datierung kann man in Rücksicht auf die altertümlichen Züge nicht unter den Nikiasfrieden heruntergehen." Cf. Picard, p. 62; Hofkes-Brukker, p. 65: 425–420 B.C. Hofkes-Brukker now prefers a date of around 420–415 B.C.: see note 26.

60 Fuchs (note 30), pp. 446f., figs. 414–415: about 410; Liepmann (note 26), pp. 27ff.: 405–395/390 B.C.; Cooper (note 25), pp. 147ff.: last decade of the fifth century; Triandi (note 17), p. 133: after 410 B.C.; Harrison, p. 104: in agreement with Liepmann.

61 Kunsthistorisches Museum 1192: Picard, p. 66, n. 2: "Noter là tout particulièrement les plis fins et capricieux du décolleté de poitrine." For the statue, see *LIMC*, vol. 2, p. 32, no. 204, s.v. "Aphrodite"; J.-P. Niemeier, *Kopien und Nachahmungen im Hellenismus* (Bonn, 1985), p. 55, no. 20, fig. 32, pp. 69f., 77ff., 80, 140ff.

62 Hiller (note 58), p. 71, n. 170. Cf. also V. M. Strocka, in E. La Rocca, ed., *L'esperimento della perfezione: Arte e società nell'Atene di Pericle* (Milan, 1988), p. 174, fig. 105.

63 Ridgway, pp. 63f.

64 Cf. Brouskari (note 50), figs. 332, 334, 340, 344, 345b.

65 Cf. P. N. Boulter, *AntPl* 10 (1970), pp. 7ff., figs. 2.7–9 and 11, pls. 1, 2, 5a, 11, 13–14, 26a, 29b; Ch. Koukouli, *Deltion* 22, part A (1967), pp. 133ff., pls. 89–94a, 97b. For the dating to 409–406 B.C., see *IG*, 3rd ed., vol. 1, pp. 474–479.

66 Cf. the Centauromachy slabs: Hofkes-Brukker and Mallwitz (note 26), pp. 51f., H2-522; pp. 53f., H3-525; pp. 54f., H4-524; pp. 58f., H6-530; and the Amazonomachy slabs, mainly pp. 78f., H17-540; pp. 82f., H19-542; pp. 83f., H20-532; pp. 89f., H23-539.

67 Agora S 182: cf. especially the projection of the body underneath the wet drapery and the sharp folds at the sides: Delivorrias, pp. 45ff., pls. 16–17, with bibl., reconstructed as an abduction scene placed on top of the Hephaisteion west pediment because of its marble. Although E. B. Harrison's hesitation about the "procrustean" proportions of this restoration (*AJA* 80 [1976], p. 210) is understandable, I nevertheless have not been able to find any other solution to the problem of its provenance. Cf. Vierneisel-Schlörb, p. 126, n. 33, p. 184, n. 22, pp. 210, 212, n. 19a; Ridgway, p. 62; Boardman, p. 148, fig. 116; Harrison, p. 105, pl. 20.4: listed among the "works of an Attic atelier continuing from the 390's to the 370's." See contra, Danner, pp. 22f., no. 143.

68 Rome, Palazzo Lazzaroni: E. Bielefeld, *AntPl* 17 (1978), pp. 57ff., pls. 35–39. Cf. Ridgway, pp. 217f.; Boardman, fig. 215; Harrison, p. 105: "forerunner of the Telauges Mnema, closer to the style of the 390's."

69 Agora S 37: *LIMC*, vol. 2, pp. 35f., no. 242, s.v. "Aphrodite," with bibl.; Harrison, p. 105, pl. 20.5: listed among the works that continue the Attic tradition from the 390s to the 370s and influence the Epidauros sculptures.

70 See note 57.

71 Akropolis Museum 2861: *LIMC*, vol. 2, p. 32, no. 203, s.v. "Aphrodite," with bibl. The play of the folds does not show up clearly in the photographs because the surface of the marble is badly weathered.

72 See note 61.

73 L. Alscher, *Griechische Plastik*, vol. 4 (Berlin, 1957), p. 220, n. 60a. Previous scholars studying the Pergamon dancer did not comment on any resemblance: A. Ippel, *AthMitt* 37 (1912), pp. 304ff.; G. Krahmer, *RömMitt* 38–39 (1923–1924), p. 183; A. Schober, *Die Kunst von Pergamon* (Vienna, 1951), p. 139, fig. 132. The same holds true for R. Horn, even though his discussion of the Pergamon dancer follows immediately after his downdating of the Este Aphrodite to around the middle of the second century B.C.: *Stehende weibliche Gewandstatuen in der hellenistischen Plastik* (Munich, 1931), p. 88, n. 5 and pp. 89f., n. 9, no. 8, pl. 36.1. It is indicative that A. Linfert, *Kunstzentren hellenistischer Zeit* (Wiesbaden, 1976), does not even mention the statue.

74 Fuchs (note 30), pp. 357f., fig. 396; A. Rieche, *AntPl* 17 (1978), pp. 21ff., pls. 10–34; Vierneisel-Schlörb, pp. 248ff., figs. 114–118.

75 N. Ceka, *Apolonia e Ilirise* (Tirana, 1982), pp. 179ff., fig. p. 180: Roman reproduction of a fourth-century B.C. type. I wish to thank Hugo Meyer, who drew my attention to the book, and to Irakli Kocollari, who translated the Albanian text. This relief is important, for it makes it certain that the head of the prototype was uncovered, allowing us to restore the original holding the helmet in the right hand, the shield in the left. The differences between the relief and the copy in Pergamon – the movement of the left arm and the additional overbelting of the peplos – do not alter the powerful impression that the two works are closely related. For the Pergamon Athena, see G. Krahmer, *RömMitt* 40 (1925), pp. 67ff., Beilage 1c; Lippold, p. 181; B. S. Ridgway, *The Severe Style in Greek Sculpture* (Princeton, 1970), pp. 130, 146, figs. 159–160; Vierneisel-Schlörb, pp. 123, 127, n. 45, with the theories that have been proposed; most recently Boardman, fig. 199.

76 Compare, e.g., the representation of Aphrodite with Eros leaning over her shoulder on the ivory from Kul-Oba in Leningrad: *LIMC*, vol. 2, p. 135, no. 1419, s.v. "Aphrodite"; ibid., nos. 863 and 997. For the Pothos motif, see S. Lattimore, *AJA* 91 (1987), pp. 411ff.

77 Lippold, p. 298, pl. 101.1 (Farnese), pl. 104.2 (Este). For the Farnese Herakles, see Fuchs (note 30), pp. 101ff., fig. 95; Vierneisel-Schlörb, pp. 450, 451f., n. 8, and the detailed investigation by P. Moreno, *Mélange de l'Ecole Française de Rome* 94 (1981), pp. 379ff.

78 E. Künzl, *Frühhellenistische Gruppen* (Cologne, 1968), pp. 36f. For the type see Vierneisel-Schlörb, pp. 446ff., figs. 219–226.

79 *LIMC*, vol. 2, pp. 30f., nos. 193–196, s.v. "Aphrodite."

80 National Museum 1601: The drawing of the relief was first reproduced in *AntPl* 8 (1968), p. 24, fig. 1, text fig. 1. Cf. *LIMC*, vol. 2, pp. 31f., nos. 200–201, s.v. "Aphrodite," and A. Delivorrias, in E. La Rocca, ed., *L'esperimento della perfezione: Arte e società nell'Atene di Pericle* (Rome, 1988), pp. 258ff.

81 H. Schrader, *Phidias* (Frankfurt am Main, 1924), pp. 314ff., figs. 284, 286, 290–292.

82 I was unable to detect it in the bibliographical references collected by G. Pesce in *EAA*, vol. 8 (1966), pp. 896ff., s.v. "Tolemaide," nor is it to be found in the series *Libya Antiqua*. My enquiries among the specialists in the field also proved fruitless.

83 For the Aphrodite from the Agora, see note 69; for another early appearance of the motif, cf. *LIMC*, vol. 2, p. 79, no. 704, s.v. "Aphrodite."

84 This kind of elaborate coiffure makes its first appearance in representations of Aphrodite at the end of the fourth century B.C. Cf. its somewhat different rendering, in the Capitoline type, *LIMC*, vol. 2, pp. 52f., nos. 409–418, s.v. "Aphrodite," but compare, ibid., no. 192.

85 See *LIMC*, vol. 2, pp. 29f., nos. 185–192, s.v. "Aphrodite."

86 Boston, Museum of Fine Arts 01.8203: *LIMC*, vol. 2, p. 32, no. 202, s.v. "Aphrodite," with the various interpretations that have been proposed. The similarities between the Boston figure and the Aphrodite from Ptolemais in regard to stance and chiton drapery folds make it very probable that it is a Roman copy as noted by M. B. Comstock and C. C. Vermeule, *Sculpture in Stone: The Greek, Roman and Etruscan Collections of the Museum of Fine Arts* (Boston, 1976), p. 97, no. 151.

87 *BCH*, Suppl. 6 (1980), pp. 148ff., no. 180, fig. 19; L. Hadermann-Misquich, ed., *Rayonnement grec: Hommage à Ch. Delvoye* (Brussels, 1982), pp. 237ff., pls. 23–24. B. Schlörb, *Timotheos* (Berlin, 1965), pp. 48ff., fig. 45, argues for the early dating of the type; see, contra, Lippold, p. 298: late fourth–early third century B.C. in connection with the Este Aphrodite; G. Heiderich, *Asklepios* (Freiburg, 1966), pp. 110ff., agrees that the prototypes for both the Asklepios and the Aphrodite were eclectic-classicizing creations of the late Hellenistic period. See also B. Holtzmann, *LIMC*, vol. 2, p. 870, nos. 31–35, p. 893, s.v. "Asklepios": second century B.C.

88 Previously noted by Delivorrias, pp. 149f., n. 639; *LIMC*, vol. 2, p. 32, no. 204, s.v. "Aphrodite." Compare the back of Poseidon on the Parthenon west pediment, F. Brommer, *Die Skulpturen der Parthenon-Giebel* (Mainz, 1963), pp. 42f., pl. 106.1. Also a figure in chiton and mantle assigned to the Hephaisteion west pediment: Delivorrias, pp. 168f., pl. 60; and the "Aura" in Athens, recently interpreted as a pediment figure (see note 44), here figures 10a–b.

89 According to Schrader (note 81), p. 314, the Venetian origin of the Este collection would imply a provenance of this work from Greece during the period of Venetian rule; the Este family, however, had estates in other parts of Italy and close links to the great Roman families. Thanks to L. Fusco, it is now clear to me that the statue originally adorned the Loggia dei Marmi of the Palazzo Ducale in Mantua, probably brought there from Rome by Giulio Romano through Giovanni Ciampolini: J. Burckhardt, in E. H. Gombrich et al., *Giulio Romano* (Milan, 1989), pp. 412ff.; L. Fusco and G. Corti, in C. M. Brown, ed., *Rome: Tradition, Innovation, and Renewal, A Canadian International Symposium in Honor of R. Krautheimer and L. Boyle* (forthcoming). See also, P. Pray-Bober, "Drawings after the Antique by Amico Aspertini," *Studies of the Warburg Institute* 21 (1957), pp. 57f., figs. 37, 40, discussing the later history of the Vienna Venus.

90 There is no information about the findspot: see F. de Clarac, *Musée de la sculpture antique et moderne*, vol. 4 (Paris, 1850), pp. 141f., no. 1449 G, pl. 632 F; S. A. Morcelli, C. Fea, and P. E. Visconti, *La Villa Albani descritta* (Rome, 1869), p. 2, no. 4, where the marble is described as coming from the Carrara quarries (Luna marble); but cf. *EA* 1106: "feinkörniger gelblicher Marmor"; J. J. Bernoulli, *Aphrodite: Ein Baustein zur griechischen Kunstmythologie* (Leipzig, 1873), p. 89, no. 25.

91 W. Amelung, *Ausonia* 3 (1908), p. 102; idem, *EA*, p. 1106; C. Watzinger, *ÖJh* 16 (1913), pp. 150f., fig. 74. Not mentioned by Lippold and Helbig[4] vol. 4, pp. 173ff. It is to be hoped that the figure will reappear in the forthcoming catalogue of the Albani collection, edited by H. Beck and P. C. Bol.

92 Not listed by Fuchs in his valuable study of the Fréjus type, in R. Lullies, ed., *Neue Beiträge zur klassischen Altertumswissenschaft: Festschrift B. Schweizer* (Stuttgart, 1954), pp. 206ff., 214ff. Cf. *LIMC*, vol. 2, p. 35, no. 241, s.v. "Aphrodite": "eine wenig spätere Variante in Rom."

93 The preserved height of the leaning Este figure is 1.14 m (the original height must have been about 1.30 m, as calculated by Schrader [note 81]), and the original height of the Albani figure must have been less than 1.385 m, which is the present total height as restored with the much too large head.

94 Cf. Amelung (note 91), p. 102: "Una statuetta della Villa Albani il cui originale dovrà la sua creazione alla generazione di Timotheos." Amelung does not, in his text to *EA* 1106, bring up the question of whether the statue is a copy.

95 Thanks again to H. D. Connelly and the Department of Art and Archaeology at Princeton University.

96 On this subject see Ghali-Kahil (note 23), pp. 128ff.; *LIMC*, vol. 1, pp. 505ff., nos. 45–55, s.v. "Alexandros."

97 For the motif, cf. Andronikos (note 55), pp. 15ff.

98 Cf. for example the representation on a lekythos with relief decoration from Olynthus: E. Zervoudaki, *AthMitt* 83 (1968), p. 22, no. 22, pls. 10.4, 11.3–4, 12.2; *LIMC*, vol. 2, p. 30, nos. 189–190, s.v. "Aphrodite."

99 Rome, Museo Nazionale Romano 124.697: attributed by L. Curtius, BrBr 766/7, and Picard, pp. 68ff., fig. 6; cf. Hofkes-Brukker, pp. 70f., fig. 25, with arguments against this attribution because of the dating to 410 B.C. and because of the weathering.

100 S. Karouzou, *AthMitt* 77 (1962), p. 184; cf., contra, Despinis (note 56), pp. 165f.; cf. Delivorrias, pp. 188f.

101 E. B. Harrison's idea, mentioned by A. F. Stewart, *BSA* 70 (1975), p. 200, n. 7, pl. 26, and by Ridgway, p. 62, n. 28, who agrees with an early fourth-century dating but disassociates the two works.

102 Schlörb, p. 74, n. 15: Tarent? Cf. H. v. Steuben, Helbig[4] vol. 3 (1969), pp. 165f., no. 2256: Attic; Gulaki, pp. 111ff., fig. 69; and J. Papadopoulos, in A. Giuliano, ed., *Museo Nazionale Romano: Le Sculture*, vol. 1, part 1 (Rome, 1979), pp. 204ff., no. 127; Danner, p. 28, no. 170, pl. 25, with a dating between 415 and 410 B.C.

103 Picard, pp. 69ff., fig. 7: Sotheby's, London, sale June 9, 1937, no. 115.

104 P. Pray Bober, "The Census of Antique Works of Art Known to Renaissance Artists," in *Studies in Western Art*, Acts of the 20th International Congress of the History of Art, vol. 2 (Princeton, 1963), pp. 84f.; N. W. Canedy, *The Roman Sketchbook of Girolamo da Carpi* (London and Leiden, 1976), p. 56, no. R86, pl. 11.

105 E. Paribeni, *Museo Nazionale Romano: Sculture Greche* (Rome, 1953), p. 15, no. 5.

106 Picard, p. 70; Vierneisel-Schlörb, p. 49; Gulaki, p. 111, fig. 68; Raftopoulou (note 17), p. 123, fig. 8; Triandi, (note 17), p. 71, n. 422.

107 After removal of the restorations the figure measured 53 inches (1.34 m), according to Sotheby's description.

108 Boston, Museum of Fine Arts 04.14: Comstock and Vermeule (note 86), pp. 29f., no. 37, with extensive bibl.; Ridgway, pp. 67f., figs. 41–42; Stähler (note 16), pp. 330f.

109 The Leda had been seen to be Attic by L. D. Caskey, *Catalogue of Greek and Roman Sculpture in the Museum of Fine Arts* (Cambridge, Mass., 1925), pp. 52ff., no. 22; cf. Schlörb (note 87), pp. 52f., n. 168: "Das Werk, das aus pentelischem Marmor besteht, dürfte daher in Attika von einem aus Ostionien eingewanderten Künstler in der Zeit kurz nach der Nike-Balustrade gearbeitet worden sein"; Lippold, p. 209, pl. 70.3, attributes the work to the leading master of the Nereid monument. On the other hand the work is thought to be Peloponnesian by Triandi (note 17), p. 130; cf. Ridgway, p. 67: "The rather cylindrical, undifferentiated treatment of the right arm and the calligraphic rendering of the drapery may speak for a Peloponnesian or South Italian origin."

110 For the history of this piece, see L. D. Caskey, BrBr, p. 678.

111 Lippold, p. 209; cf. Ridgway, p. 67: "In fact, its similarity with the Louvre acroteria is striking and probably meaningful."

112 Ridgway, p. 68: "Since the specific mythological allusion should preclude a mechanical duplication of the figure in mirror image, it is legitimate to wonder what adorned the opposite corner. Perhaps only a Ganymede-and-the-Eagle could make a suitable pendant, but the diversity of the figures would still be unusual."

Boardman, p. 176, fig. 140, rejects the interpretation as an akroterion: "probably an independent offering." Danner, p. 93, A33–A34, accepts the original unity of the Louvre sculptures and the Boston Leda, but since the latter "nicht als Akroterfigur in Frage kommt, müssen die Figuren Teil einer Giebelkomposition oder einer freiplastischen Gruppe gewesen sein." However, the invisible yet significant presence of the eagle may be conceived of only in relation to the surrounding aerial space, which can hardly be expressed within a confining pedimental triangle.

113 Comstock and Vermeule (note 86), p. 29: "If not directly connected with the building as carried out or projected, the Leda and the Swan could have been fashioned for a naiskos or architectural pedestal in the sacral area."

114 Delivorrias, p. 188, contradicting Karouzou's identification as Boreas and Oreithyia: *AthMitt* 77 (1962), pp. 178ff., pls. 44–48; Despinis (note 56), pp. 162ff. See A. Delivorrias, Ηορος 2 (1984), pp. 83ff., esp. 84ff. with further arguments in favor of the abduction of Helen by Theseus; cf., contra, *LIMC*, vol. 3, p. 138, no. 66, s.v. "Boreas."

115 For the quality of the folds and a dating in the early fourth century B.C., see Harrison, p. 104, pl. 19.3.

116 Not to mention the hesitations recently expressed by V. Petracos as to whether it was intended as an akroterion at all, see: H. Kyrieleis, ed., *Archaische und klassische griechische Plastik*, Akten des Internationalen Kolloquiums vom 22.–25. April 1985, in Athen, vol. 2 (Mainz am Rhein, 1986), p. 89, n. 2. Compare, however, M. M. Miles, *Hesperia* 58 (1989), p. 196: "the front horizontal geison blocks are 0.0375 m higher than those of the flanks; the added height may have been intended to strengthen the floor of the pediment to carry statuary." On the akroteria of the temple, see ibid., pp. 212–214. The attribution of the group to the Rhamnous temple has been challenged by E. B. Harrison: see M. M. Miles, *The Temple of Nemesis at Rhamnous* (Princeton, 1980), pp. 138f., and Danner, pp. 25f., no. 157.

The Quarrying Techniques of the Greek World

M. Waelkens, P. De Paepe, and L. Moens

In 1984 an interdisciplinary team sponsored by the Belgian National Fund for Scientific Research was set up in order to sample systematically all major quarries of white marble in the Mediterranean[1] and to register all traces of ancient quarrying that can still be seen in them. The team includes a geologist (P. De Paepe) and a chemist (L. Moens), who are responsible for the analysis of the samples,[2] as well as an archaeologist (M. Waelkens), whose task it is to study all traces of extraction and of dressing the extracted material. This last aspect of our research has become a kind of rescue operation, since modern activities in most ancient quarries are gradually destroying all traces of older exploitation. The results are presented in this paper together with those already registered independently by Waelkens since 1976 in numerous other, mainly smaller, quarries of the ancient world.

Greece has a very old tradition of marble carving, going back to the late Middle Neolithic (circa 5000 B.C.) and the Late Neolithic period (circa 4500 B.C.), when small anthropomorphic marble figures were already being carved on the mainland and on the Cyclades.[3] Whereas production gradually seems to have ceased in mainland Greece and on Crete, the Cyclades witnessed a flourishing period of marble sculpture during the Early Bronze Age (third millennium B.C.). Both in the Neolithic and in the Archaic phase of the Early Cycladic culture, the material used for the figures and for stone vessels was basically pebbles and boulders gathered from the beaches and already partly worked by the action of the sea. This explains the small dimensions of the artifacts, which were carefully completed by laboriously chipping away and abrading the stone. The artists used emery and obsidian for making incisions and sand and pumice for smoothening the surface.[4] The introduction of bronze tools during the classical Keros-Syros phase of the Early Cycladic (somewhere between circa 2700 and 2100 B.C.) made it possible to improve the preparation of stones for sculpting and to break, by means of a crowbar, larger lumps of stone that had already been separated from the parent rock as a result of erosion.[5] Yet even then, one could hardly describe those activities as real quarrying.

During the prehistoric phases of their past, Egypt and Mesopotamia also produced stone vessels and other artifacts (such as palettes in Egypt) for domestic or religious use. But here again the dimensions were small.[6] As a result, the material must not have been extracted in real quarries but may have been collected or broken on much eroded spots.

On the other hand, there can be no doubt that real quarrying started in Egypt, where its appearance was connected with the introduction during the Archaic period (circa 3100–2686 B.C.) of an architecture based on dressed stone. Roughly dressed limestone, and even granite, were already used in some tombs of the First Dynasty, while carefully dressed limestone blocks, some of them of really large dimensions, made their appearance as interior lining of subterranean burial chambers dated to the time of the Second Dynasty.[7] Under the same dynasty sizable blocks of granite were also used for free-standing stelae.[8]

The Third Dynasty (circa 2686–2613 B.C.) introduced carefully dressed stones for monumental architecture above ground. It certainly was no coincidence that monumental sculpture (limestone, granite) started at the same moment. The material used in King Djoser's funerary temple consisted of rather small blocks of dressed limestone, besides granite slabs (in the tomb itself).[9] But by the time of the Fourth Dynasty (circa 2613–2494 B.C.) granite from Aswan was already broken in enormous blocks, which were shipped to Giza.[10]

There are still many unanswered questions concerning the earliest Egyptian quarrying techniques, but it seems certain that the technique of isolating blocks from the parent rock by cutting narrow trenches all around them must have been invented here. For softer stones, such as sand- and limestone, these trenches at first were cut by means of copper punches, whose edges had been hardened through hammering. This weak instrument left short and irregular traces on the quarry walls.[11] Starting with the New Kingdom (circa 1500 B.C.) the copper punches seem to have been replaced by stronger bronze punches, whose traces at first were somewhat longer and usually arranged in a herringbone pattern. From the Nineteenth Dynasty onward the tool became longer and stronger, creating long, oblique, almost parallel, but many times interrupted grooves.[12] Despite the fact that iron occurred in Egypt already in the second millennium B.C., it does not seem to have been used for tools before the eighth or even the sixth century B.C.[13] Ptolemaic or Roman quarry faces worked with iron punches display long, parallel grooves.[14] Picks do not appear to have been introduced as a quarry tool before the Ptolemaic period. Traces of this instrument can be found in some quarries of soft limestone near Alexandria.[15]

FIG. 1

Quarry trench around a block on Mount Hymettos. Photo: authors.

Once the blocks had been freed on five sides, they still had to be separated from the bedrock below. Whenever possible, the quarrymen may have chosen already existing natural flaws (such as clay intrusions) as the upper and/or lower edge of a layer to be extracted. However, where the bed of pure stone was too high, they may at first have split off the blocks below, by applying the same method as that for cutting lateral trenches.[16] Egyptian quarrying techniques are even more debated as far as the extraction of hard stones, especially granite, is concerned. Most scholars agree that, at least until the end of the New Kingdom, the quarry trenches in granite layers were cut by means of a pounding technique, using hard dolerite hammers, which were repeatedly pounded on the surface.[17] Some scholars believe that this process was facilitated by first heating up the hard rock surface and then giving it a thermic shock by throwing water over it, thus weakening the stone.[18] An inscription from Wadi Hammamat, dated to the Middle Kingdom, has even been connected with this practice.[19] Whatever the exact sequences of the technique, the Egyptians may at first have tried to trim down as much as possible larger stones, which were already separated from the parent rock as a result of erosion.[20] Yet, once they started to produce huge monolithic blocks, such as obelisks,[21] they had to develop more elaborate quarrying techniques, cutting real trenches in the solid mass of stone, as they had already done for centuries in quarries of softer stone. There is still no agreement concerning the date at which the primitive pounding technique was replaced by the more advanced method using iron punches. Some scholars believe this may have happened already under the Saitic Dynasty,[22] others, however, maintain the change did not occur until the Ptolemaic[23] or even the Roman period.[24]

Yet, the main problem about Egyptian quarrying techniques concerns the method used for splitting off hard stones exclusively below. Some scholars believe that this was achieved by undercutting the blocks on one or several sides and then putting pressure on one upper side by pushing or hammering wooden beams down one of the quarry trenches.[25] This theory is mainly based upon the assumption that wooden wedges, which were made to swell by soaking, could not be used for splitting hard stones, and on the opinion that iron wedges were not introduced in Egypt before the Ptolemaic period.[26] Yet, there are several testimonies that granite sometimes was, and in some places still is, split by means of soaked wooden wedges.[27] On the other hand, the late appearance of wedge-holes in Egypt and the typological development that has been proposed for them[28] has recently been challenged by C. Nylander. This scholar does not exclude the possibility that the Egyptians, after a period during which they used wooden wedges placed in holes cut with dolerite hammers, may already have introduced iron wedges during the eighth or seventh century B.C.[29] Some wedge-holes (for wood) have even been noticed on stones dated to the Old Kingdom.[30] Whatever the date of the introduction of iron wedges in Egypt, there as well as in Greece different types of wedge-holes may relate more to specific practical problems than to a chronological development. If wedges were already used in Egypt before the Saitic period, and if iron was not used there for making stonemason's tools before the eighth or even the sixth century B.C., the oldest wedges can in fact only have been made of wood, since copper or bronze wedges certainly would break if hammered against hard stones such as granite. The whole matter should therefore be studied all over in the quarries, since wooden wedges must have left very characteristic traces. On the other hand, the use of wooden wedges may not have been the only splitting technique. Larger stones, such as the obelisks, most probably were simply undercut, since this was less risky than using wedges. Traces of it are clearly visible at Aswan.

Whatever the solution to this problem, Egypt most certainly played a predominant role in the development of quarrying techniques. First of all it created a society that made the development of highly specialized quarryworkers possible.[31] Even if a possible Egyptian origin of quarry wedges may be problematic, there can be no doubt that the quarrying system using quarry trenches originated there.

From Egypt this method must have spread very rapidly all over the Eastern Mediterranean, including the Aegean world, where it first took hold on Crete. The Minoans used soft stones (such as chlorite, steatite, serpentinite) primarily in the earlier periods for vessels or for molds for casting bronze tools. They may at first have relied on a kind of natural presorting of their material; in fact, they probably selected blocks that had already been mechanically presorted by the

FIG. 2

Quarry on Mount Hymettos, with exploitation on a single level. Photo: authors.

natural force of water erosion.[32] Even later, hard limestones and various schists and conglomerates most likely were gathered up or pried loose from hillsides.[33] A soft stone like gypsum may not have needed a specific quarrying method but could have been extracted by means of simple tools for cutting wood.[34] Yet, at the latest around 1900 B.C., the Minoans, using tools of hardened bronze, must also have started systematically extracting soft stones, such as porous limestone, sandstone, or *ammoudha* (a calcareous sandstone). The Minoan origin of some of those quarries, which are concentrated on eastern Crete, is confirmed by sherds found in or near the quarry trenches.[35] All these quarries are situated near the sea, no doubt because they were dependent on sea transport. Some of them were started on a clifflike shore or in a natural ravine formed by a small stream, as was the case at Mochlos. Moreover, the seawater may also have been used to soak the rock, which reduced the wear on the still-weak bronze tools.[36] Here again the quarrying technique consisted basically of cutting trenches around the blocks, a method that most probably had been introduced from Egypt. In some cases a grid of incised lines seems to have been laid out in advance to serve as guidelines for cutting the channels.[37] Sometimes only one layer of blocks was taken away, thus creating a vertical recession.[38] Yet, a stepped extraction over several levels seems to have been the normal practice.[39] Although the weathering of the stone in most cases precludes any possibility of identifying the tool by means of which the channels were cut, there are at least some blocks or quarry faces where the grooves clearly indicate that the cutting instrument was a kind of pick mounted on a long handle.[40] It left oblique, sometimes almost perpendicular, but always slightly curved traces on the quarry walls. Some Minoan bronze picks with long curving blades, pointed at one end, flat and sharpened (for chopping) at the other, may have been used for

FIG. 3

Stepped extraction in one of the quarries on Paros. Photo: authors.

this purpose.[41] Here, as in Egypt, the method used for the final separation of the blocks below is still largely unknown. But the uneven way in which some blocks are broken suggests that they were split off, either by using a pry or, according to some scholars, by means of wooden wedges.[42] Yet, it must be emphasized that thus far no traces of wedge-holes have ever been identified in the Bronze Age quarries of Crete, which makes the use of wedges rather doubtful. In the *ammoudha* quarries at Mochlos, however, a straight line running along the cut face of the stone in one of the quarry sections may suggest a system of scoring by means of a chisel, in order to split off the blocks from below.[43] Since a similar method was also used later in the Greek marble quarries, the Minoan way of splitting off blocks of softer stone may in fact have been to free the blocks on four or five sides first and then causing them to crack below by cutting a deep groove near the intended lower edge. Soaking the stone may have enhanced the success of this operation.

In mainland Greece quarried blocks apparently did not appear in architecture before the LH II (from the fifteenth century B.C. onward), when some large-scale blocks (soft limestone and conglomerate) first occur in tholoi and later also in defense walls. Some of the quarries from which they were extracted may still exist, but they need further study.[44] The colored Peloponnesian marbles used by the Mycenaean architects for decorative purposes[45] are so small that they need not have been quarried.

The collapse of the Mycenaean civilization almost certainly also meant the total disappearance of quarrying techniques from the Aegean for several centuries. Therefore it is very unlikely that the Archaic Greek quarrying techniques may be traced back to earlier, local Bronze Age practices.

The only region, besides Egypt, where Bronze Age quarries in fact may have continued, was the area of the neo-Hittite

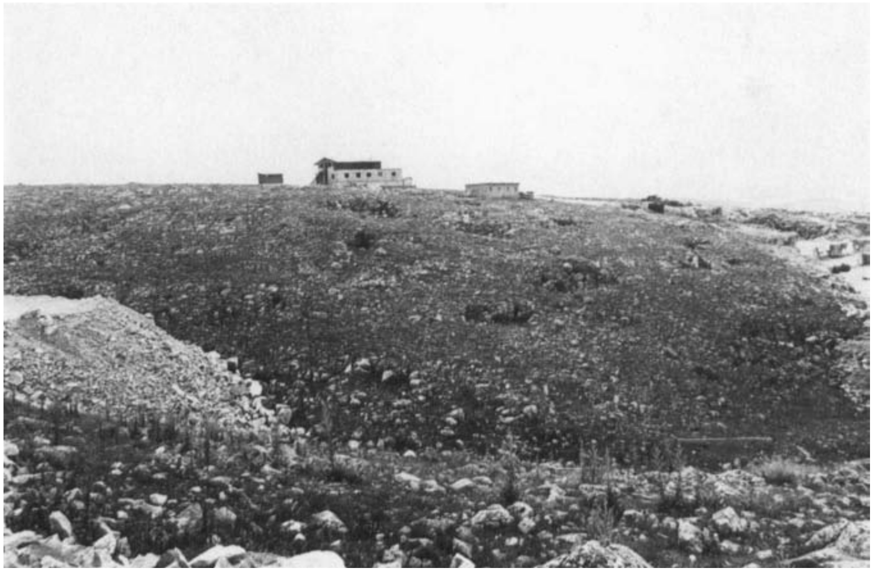


FIG. 4

Probably pre-Imperial, widely dispersed quarries at Dokimeion. Photo: authors.

civilization in southern Turkey and northern Syria. The impressive remains of the Hittite Imperial architecture clearly illustrate that the Hittites knew how to quarry large limestone, conglomerate, and even basalt blocks, at the latest from the fourteenth century B.C. onward. Several quarries are known, both from the Hittite and from the neo-Hittite period, but all still need to be studied in detail.[46] What has already been published indicates that the Hittites again used the quarry trench method, which may have spread to Anatolia from Egypt. The date of some of the Boğazköy quarries has recently been placed in the Classical period.[47] Yet, there are very strong indications that the Hittite capital, at the latest by the thirteenth century B.C., had a very well-developed system of quarrying, which can best be compared with that of the oldest Greek quarries. In fact the quarries known as Kesikkaya and Kızlarkayası both present the same kind of regular, horizontal grooves – without any doubt made by a light pick – as those found in pre-Imperial Greek quarries. Yet, they do not necessarily belong to the post-Hittite occupation of Boğazköy, since completely identical traces can be seen inside the "basin," dated to the first half of the thirteenth century B.C., near the propylon of the Great Temple.[48]

Therefore, the kind of quarry pick used by the Greeks may already have been developed by the Hittites, who used it on softer stones, such as limestone and conglomerate. The neo-Hittite empires of the northern Levant may then have passed it on to the Greeks, together with so many other elements of their archaic architecture and sculpture. By then, however, perhaps thanks to an Assyrian innovation,[49] the instrument was already made of iron, which was much better suited to quarry harder stones, such as marble.

Although it has been commonly assumed that the Greeks borrowed their quarrying techniques directly from Egypt,[50] there are very strong indications against such an origin. First of all the

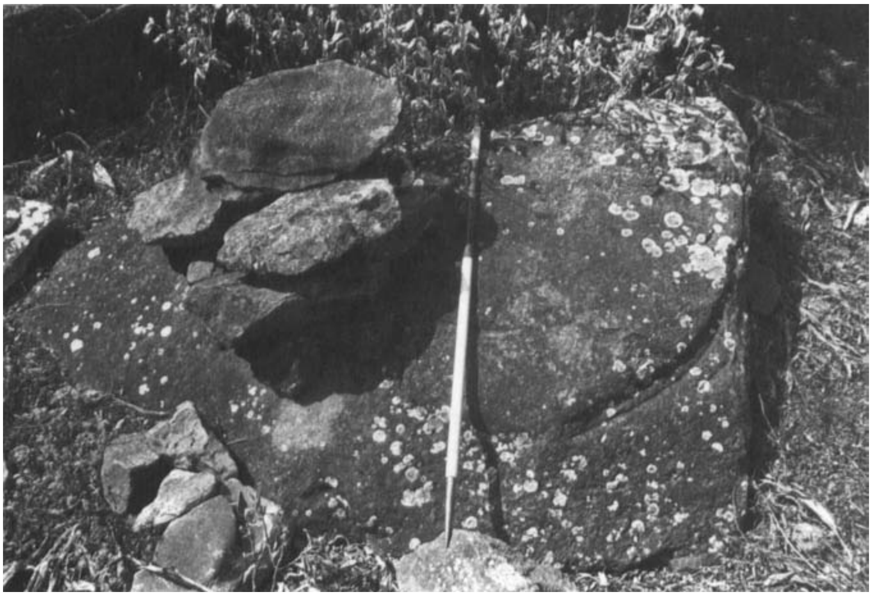


FIG. 5
Trace of an individually extracted column drum on Paros. Photo: authors.

instrument used by the Greeks for quarrying was a light pick, not a punch as was common in Egypt. Even if there can be no doubt that the quarry trench system used by the Greeks had been developed in Egypt, it had spread all over the eastern Mediterranean by the time it reached Greece. Moreover it may already have existed in Greece well before the renewal of contacts with Egypt in the seventh century B.C. In fact, before quarrying started to serve mainly architectural purposes, it must have been developed in Greece to meet sculptural needs.

The earliest surviving Greek stone sculptures, of limestone, were made on Crete, from the end of the ninth century B.C. onward. In this context it is very important to emphasize that the orientalizing style of these sculptures, together with their carving technique, are considered to have been reintroduced from the general area of Syria and the neo-Hittite kingdoms, perhaps even by immigrant artists from that area.[51] Their sophisticated technique may have disappeared with them. But when, starting in the second quarter of the seventh century B.C., Crete developed the Daedalic style, which also flourished on the Cyclades and elsewhere in Greece until the end of that century, this style appears to have been developed under the influence of north Syrian craftsmen or imports.[52] The earlier works, all of small size, were made of limestone. When, somewhere around the middle of the seventh century B.C., marble sculpture developed on the Cyclades, where the impetus, if not the artists as well, may have come from Crete, some of the first figures had very thin, slablike dimensions, as is clearly illustrated by the statue of Nikandre[53] and by the Naxian colossus on Delos.[54] This may be due to still-primitive techniques of splitting off the blocks from below, since even sixth-century B.C. quarries show many irregular breaking surfaces. The first marble sculptures from the mainland – being most probably the Peloponnesian perirrhanteria, developed during the

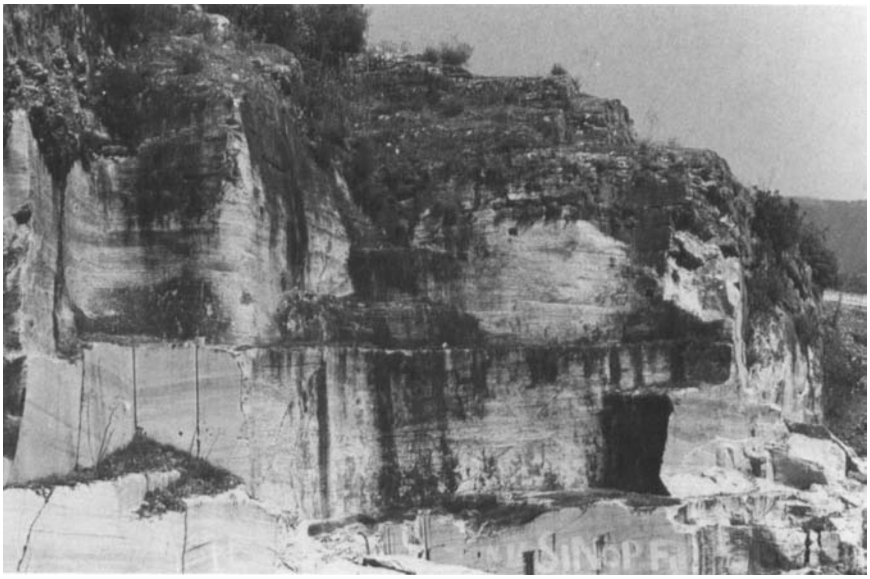


FIG. 6

Sixth-century B.C. quarry walls at Belevi dated by means of graffiti. Photo: authors.

late seventh century B.C. – again represent a type of human figure that was derived from the East, and most probably even from Syria.[55] Seen in this context and considering the fact that the oldest still-preserved traces of Greek quarrying – those at Apollonas on Naxos – bear a very strong resemblance to the grooves visible in the already mentioned Hittite basin at Boğazköy, it is more than tempting to suggest that the Greeks not only were influenced by the neo-Hittite civilization in their first stone sculptures but also that they borrowed their quarrying techniques from there. The renewal of relations with Egypt in the seventh century may only have led to the first monumental sculptures and to the birth of megalithic architecture in Ionia. This may have stimulated the Greeks to improve their quarrying techniques to obtain larger blocks of stone, in a hard material such as marble.[56] Yet, the main iron tool used for this, a light quarry pick, thus far is without any parallels in contemporary Egypt. As mentioned above, it may already have been used in the limestone quarries delivering the material for the first stone sculptures, and it may originally have been introduced from the neo-Hittite civilizations in Syria. Whether this implies that the complete Greek quarrying techniques, as known from the first Archaic quarries, have to be considered a Syrian import, still remains uncertain. In fact there is a considerable gap between the introduction of stone sculpture in Greece and the oldest preserved Greek quarries[57] of the early sixth century B.C.(?). These quarries already used a fully developed technique of iron wedges to split off the blocks from below. Considering the different instrument – a pick instead of a punch – used for cutting the preliminary quarry trenches, and the very much debated, perhaps late introduction of iron wedges in Egypt, it is rather unlikely that the Greeks got their wedges from there. If, as well, they were not introduced from Syria, where this aspect of quarrying to our knowledge has not been studied yet, they could also represent a technical improvement developed by the Greeks themselves.

Whatever the origin of the Greek quarry wedges, Archaic Greece witnessed a real explosion of quarrying, be it poros, limestone, or marble, caused by the quick development of sculpture and by the petrification of its monumental architecture, where quarried stone very rapidly replaced the *lithoi logades* (Thuc., IV.4), or fieldstones, gathered up from the ground, which thus far had been used in foundations or socles of mudbrick buildings. The first complete marble buildings appeared already during the sixth century B.C., both on the Cyclades and on the Ionian coast.[58] It thus comes as no surprise that by the end of that century most major quarries of the Greek world, be they in what is now modern Greece[59] or in Anatolia,[60] were already fully active. Yet one of the main problems in studying Greek quarrying techniques remains identifying quarries or quarry sections for which one can propose an absolute date. In fact, most major quarries, because of the quality of their material, have been active for several centuries, each new operation destroying most, if not all evidence of older ones. Sometimes, as for instance in the Belevi quarries,[61] graffiti or inscriptions may help us date specific sections of a quarry face, but this kind of evidence is rather exceptional. Therefore, the best method is to find smaller quarries with a short-lived, well-documented, and reliably dated exploitation, ranging in date from the Archaic until the end of the Hellenistic period.

Throughout this time and even until the end of the Byzantine age, the basic principles of quarrying appear to have remained unchanged: After clearing the surface above, the first step was to isolate a block on at least four, but usually on all five sides, by laboriously cutting trenches all around it (fig. 1). The process could be simplified by establishing a horizontal working floor upon which a kind of grid made of the quarry trenches was imposed, thus reducing the number of trenches that had to be cut for each individual block and achieving a convenient working platform. The exploitation was sometimes only continued downward, especially on very flat grounds, which considerably reduced the possibilities of exploitation because of the problems of evacuating the extracted material (fig. 2). Most Greek quarries of this type thus were only continued over one or two layers at the most, sometimes leaving a very neat "negative" impression of the extracted blocks.[62] Usual practice, however, was to quarry on slopes, where the exploitation could be continued downward and outward, which made transportation of the extracted stone and of the material that had to be dumped much easier. Such exploitations sometimes continued over considerable heights, eventually leaving a kind of stepped

FIG. 7

Entrance to the "Grotto of Pan" on Paros. Photo: authors.

quarry face showing nice traces of the instruments used to cut the trenches (fig. 3). Since the Greeks appear to have quarried only particular consignments of marble, clearly specified as far as dimensions and finishing were concerned, they may never have started building up stocks of already quarried and partly finished blocks or architectural elements, as the Romans would do, at least from the first century A.D. onward. Therefore no more blocks were extracted than absolutely necessary, and the entrepreneurs tried to find very pure layers as near the surface as possible. As a result many Greek quarries were dispersed over a large area (fig. 4), consisting of isolated spots where suitable material had been extracted (fig. 5).[63] Yet, quarries serving the larger cities may already have reached considerable dimensions even in the Archaic period. This is very well illustrated by the steep, sixth-century quarry faces of the Belevi quarries (fig. 6), which most probably delivered the material for the Artemision.[64] In the fifth century B.C. some of the limestone quarries serving Athens and Syracuse had acquired such dimensions that they could be used as a place of detainment for large numbers of prisoners of war.[65] As shown in the fourth-century B.C. relief in one of the tunnels on Paros in which the immaculate *lychnites* marble was quarried, if necessary the Greek quarrymen even had the technical skills to exploit veins of pure marble in underground quarries (fig. 7).[66]

Usually, however, the exploitation could be achieved in open-air quarries. There the traces of the instrument by means of which the quarry trenches were cut are often well preserved. One type of trace is made of very regular, almost horizontal, or only slightly curved grooves, consisting of shallow ledges, which seem to be the result of crushing (fig. 8).[67] These marks can only have been produced by a long-handled, rather light pick with a very sharp point on at least one end. The instrument may have resembled the "tykos" of modern

FIG. 8

Traces of the light quarry pick in a Hellenistic quarry in the Kaystros Valley, Turkey. Photo: authors.

FIG. 9

Traces of the light quarry pick in one of the trenches around the colossus at Apollonas on Naxos. Early sixth century B.C. Photo: authors.

Greek quarry workers,[68] as well as the "escoude" of the quarries of Gaul,[69] or the modern quarry pick used for softer stones in Germany;[70] the same type also occurred in Germany in antiquity, as is shown by a sketch on the wall of a tuffo quarry at Kruft[71] and by discoveries in the quarries themselves.[72] The tool could have been the *latomis* of ancient Greek sources.[73] This rather weak instrument may have been developed for quarries of softer stones and only later have been introduced for quarrying marble as well.[74] It forced the quarrymen to move on after each stroke, for it could not penetrate very deep into a hard surface. It thus created very characteristic, almost horizontal, crushed grooves. This type of pick can now clearly be identified as the characteristic tool of the Greek quarrymen. In fact its traces are found on quarry walls that can be dated from the early sixth century B.C. right into the Roman Imperial period. For the sixth century B.C. we can thus mention the trenches around the colossus at Apollonas (fig. 9) and those of the quarries at Phlerio on Naxos, as well as the quarry faces at Belevi, both those of the Artemision quarry and those belonging to the nearby tumulus (fig. 10).[75] To the middle of the fifth century B.C. belong the traces of the same tool on the rock-cut north and east sides of the East Room of the theater at Thorikos, which may also have served as quarry for its renovation. Fourth-century B.C. examples can be seen in some of the limestone quarries near Delphi.[76] We noticed several other examples, dated to the Hellenistic period at Priene (near one of the city gates), on rock-cut monuments in the Bay of Kekova (Lycia), and on the mausoleum at Belevi (fig. 11).

The light pick was very well adapted to extract blocks of well-specified dimensions, work which required great precision and which moreover could be carried out by only a few people. In fact, the tool allowed very careful work, creating almost vertical quarry faces, without much loss of material during the operation (fig. 12). Since

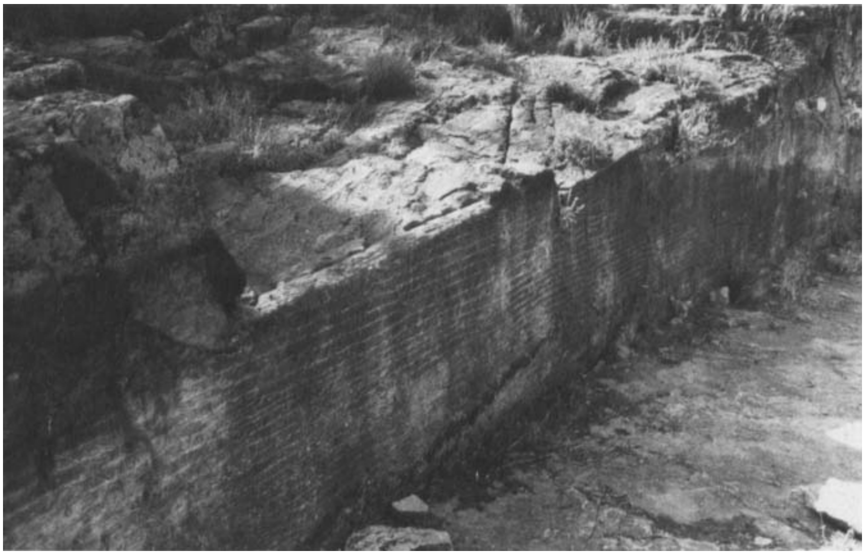


FIG. 10

Traces of the light pick in the quarry around the tumulus at Belevi. Sixth century B.C. Photo: authors.

quarrymen using this light pick had to move on along the same line after each stroke, it was a rather time-consuming exploitation, carried out by a few men – with a larger team the men would have been in each other's way. All of this made the pick an ideal instrument for rather small-scale operations carried out by private individuals.

This may explain why the light pick from the late first century A.D. onward gradually seems to have been replaced by a bulkier type of pick-hammer producing deep, strongly curved grooves (fig. 13), many times arranged in a garlandlike pattern ("a festoni"), indicating the range of action from a particular position.[77] This instrument may have been a lighter version of the heavy and stocky pick-hammer that nowadays is still used for dressing the blocks after quarrying,[78] some examples of which have also been found inside ancient quarries.[79] Because of the bulky body of the instrument, especially near the handle, the quarrymen had to move slightly outward as they went deeper along the quarry face (fig. 14). To counteract this movement they had to change direction constantly, reversing the direction of their strokes.[80] All of this created a very irregular quarry face and as a result also a greater loss of material. The main advantage, however, was that the instrument allowed a much quicker exploitation, since it could be used simultaneously by several men working next to one another. In fact, the greater weight and force of the tool made it possible to penetrate deeper into the stone and thus cut deep curved trenches between the legs or at one side of the quarrymen, who did not have to move on very often. The introduction of this instrument, apparently during the (later?) first century A.D.,[81] may thus have been connected with the massive reorganization of the whole quarry system under the Empire. Now the quarries had to meet the requirements of real mass production, building up enormous stocks of preshaped material. Although the new system of exploitation may have originated from the

FIG. 11

Traces of the light pick on the interior of the mausoleum at Belevi. Third century B.C. Photo: authors.

FIG. 12

Graeco-Roman steep quarry wall with traces of work with the light pick, on Mount Hymettos. Photo: authors.

major quarries, most of which by now had become Imperial property, it was very rapidly also introduced in private and municipally exploited quarries. Where the older pick continued to be used, such as for instance on Mount Hymettos and in most quarries on Thasos (fig. 15), this may perhaps be explained either by the conservatism of the local quarryworkers, or by the fact that working conditions similar to those of the pre-Imperial period still prevailed there. Traces of other instruments for cutting trenches, such as shorter handpicks or punches, are very rare and seem mainly to have been connected with smaller operations or with "corrections" on quarry walls.[82]

If the system of cutting trenches around blocks in the quarries thus seems to have remained fairly consistent throughout Greek antiquity, the ways of splitting off the blocks from below show much greater variety, as far as the shape, the overall dimensions, the reciprocal spacing of the wedge-holes, and their combination with other techniques aiming at better control of the breaking line, are concerned. At one point Joseph Röder proposed an elaborate typology of these characteristics, which would have corresponded to a very specific chronology.[83] Very rapidly his theories were challenged by other scholars,[84] however, and eventually Röder himself came to the conclusion that his scheme perhaps only worked for the Egyptian granite quarries.[85]

As the many irregular breaking surfaces in the quarries show, splitting of the blocks from below must undoubtedly have been the riskiest operation of the whole extraction, for which the experience of the quarrymen and their knowledge of the characteristics of the stone to be extracted counted most. Here, even more than for cutting the quarry trenches, the technique had to be adapted to such features as the stratification of the stone, the presence of natural

FIG. 13

Traces of the bulkier pick, on a quarry at Aliki, Thasos. Photo: authors.

FIG. 14

Irregular quarry face cut with the heavy pick at Aphrodisias. Photo: authors.

FIG. 15

Late antique quarry wall with traces of the light pick at Aliki, Thasos. Photo: authors.

FIG. 16

Archaic quarry at Apollonas, Naxos. Left and right are outlines of the extracted blocks as defined by means of a punch. In the center, wedge-holes, and in front of them irregular holes, cut to facilitate the hammering on the iron wedges. Photo: authors.

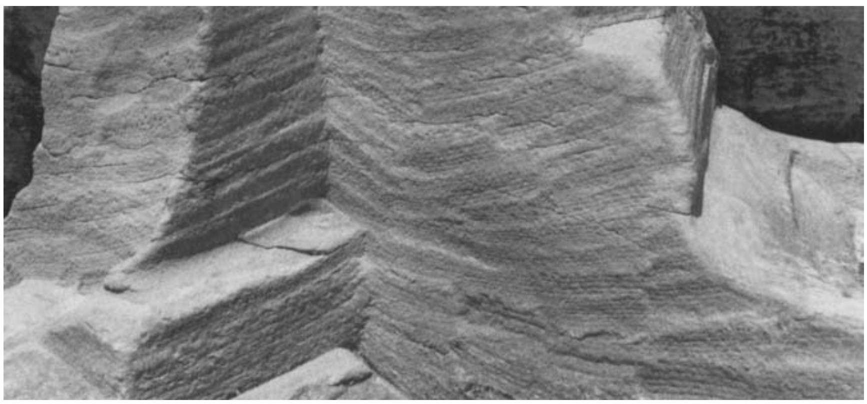


FIG. 17

Archaic wedge-holes in the quarry around the tumulus at Belevi. Photo: authors.

FIG. 18

Archaic traces of the "pointillé" technique at Apollonas, Naxos. Photo: authors.

cleavages, the way the stone usually split, and the dimensions of the block that had to be separated. Therefore, I believe that quarrying in antiquity was always carried out by families of free quarryworkers, passing on their experience from one generation to the other, as nowadays is still the case in Italy and Turkey. Unexperienced slaves or prisoners could only be used for dumping the wasted material. Considering the above-mentioned facts, the variety of methods used to split off blocks from below may primarily relate to very specific local conditions, not to a well-established chronological sequence. In fact, most techniques can already be found in the Greek quarries from the Archaic period and continue to be used from then on. This does not, however, exclude the possibility that eventually the dimensions of the wedges, especially iron wedges, became more standardized than they were at first.[86] Yet, even this aspect still needs to be studied more carefully.

Iron wedges were already used in Greece during the first half of the sixth century B.C., as is clearly indicated by the traces of exploitation around the colossus at Apollonas on Naxos (fig. 16). By means of a light quarry pick, 33-to-60-cm-wide trenches were cut between the blocks (which were themselves 85 to 105 cm wide) before the blocks were removed. At one long side the dimensions of these blocks were very clearly outlined through closely spaced punch strokes,

FIG. 19

Groove cut with a chisel, containing several wedge-holes, at Filippi. Photo: authors.

FIG. 20

Groove indicating the level above the natural grotto up to which quarrying could continue, at Spilia, Mount Pentelikon. Photo: authors.

not drill-holes as was suggested in the past.[87] This operation must already have weakened the stone and may have caused internal cracks along the intended line of breakage. On the other side(s), a series of irregular holes was cut at relatively widely spaced intervals, corresponding to carefully prepared wedge-holes underneath the blocks themselves. The purpose of the irregular holes can therefore only have been to facilitate the hammering on the wedges, which as a result can only have been made of iron.[88] A similar system, with more closely spaced wedges, is also visible in an Archaic quarry at Phanari on Thasos.[89] That iron wedges were in fact used during the sixth century B.C. is further proven by the quarrying traces around the contemporaneous tumulus at Belevi (fig. 17), where some of the closely spaced wedges used to split off blocks for the krepis of the gravemound were found in situ.[90] Late sixth- or early fifth-century B.C. examples occur at Persepolis, where they may have been made by Greek quarrymen,[91] as well as on Aegina.[92] In both cases we are dealing with limestone. Some iron wedges have been discovered in situ in some of the Corinthian limestone quarries dated to the late fifth or early fourth century B.C.[93] The fourth-century B.C. limestone quarries of Delphi also contain several traces of closely spaced, rather short wedge-holes, which should be connected with iron wedges.[94]

Since one of the main problems with the wedging technique is the irregularity of the resulting break line, people appear very quickly to have developed devices to gain better control over the breakage. One solution was to connect widely spaced wedge-holes by a line of punch strokes. Sometimes one thus developed a real "pointillé" technique, consisting of closely placed punch or point strokes on three or

FIG. 21

Groove marking the edge of the irregular upper surface (above, right) in a late Hellenistic to early Roman quarry near Sebaste, Turkey. Photo: authors.

more sides of the blocks, which occasionally appear to have replaced the wedge-holes completely. That this method, which usually is considered to have been a rather late phenomenon,[95] existed already during the Archaic period is shown by the quarries at Apollonas on Naxos and by those at Belevi (fig. 18). It seems to have been used mainly for the extraction of smaller blocks, which could be removed by putting pressure on one side. Yet, there also existed better techniques to control the splitting. One method was to place the wedges in a continuous groove, cut with a chisel (fig. 19).[96] This groove, through internal cracks developed during its cutting, could certainly influence the direction in which the stone eventually would split. The system occurred from the sixth century B.C. onward, as is shown by the quarries at Belevi,[97] and it can still be seen on many Greek quarry faces. Sometimes the groove seems to have been cut in advance to facilitate the extraction along the steep and high quarry walls, when people decided to expand the quarry. In other cases, however, the groove has been cut in advance as a kind of guideline, showing the quarrymen, for instance, where, at a later stage, the extraction of good material could start or where it had to stop (fig. 20), indicating that the surface above or below it was either too irregular as a result of quarrying (fig. 21), or that the stone above it was of a different quality (fig. 22). Sometimes, for instance in some of the quarries on Karystos, the stone broke so easily that it could be split off by simply placing a crowbar inside the precut groove.[98] A last method, applied on Thasos until quite recently, placed the wedge-holes inside shallow

FIG. 22

Grooves marking the change in color in a quarry at Aphrodisias. Photo: authors.

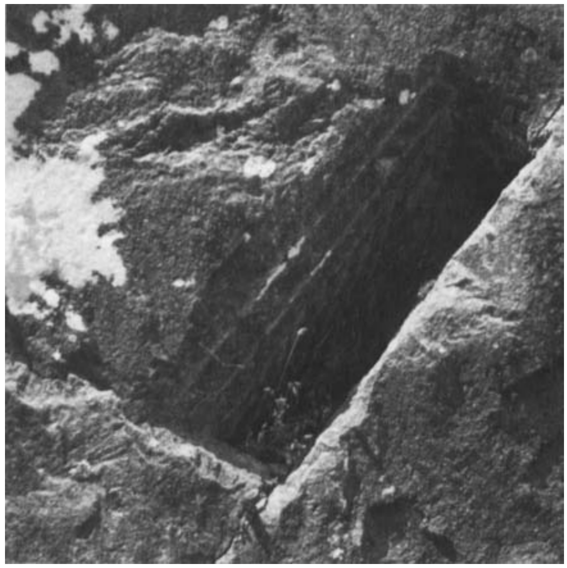


FIG. 23

Traces of stones, vertically split by means of wooden wedges, in a nineteenth-century quarry on Mount Pentelikon. Photo: authors.

FIG. 24

Wedge-hole for a massive wooden wedge, cut by means of a chisel, at Doliana. The cracks were probably caused by water that froze inside the holes. Photo: authors.

trenches.[99] Examples of this method already occurred in late Archaic or early Classical Persepolis.[100]

All of the above-mentioned techniques concerned the use of iron wedges. It has become clear that people in antiquity also used wooden wedges, examples of which have been found in some Roman quarries.[101] Although, thus far, no Greek wooden wedges seem to have been discovered, it is apparent that some of the wedge-holes still visible in ancient and modern quarries of Greece were cut in order to receive wooden wedges. They can clearly be distinguished from the iron-wedge holes by their usually very wide spacing and by their very large dimensions,[102] carefully cut with a chisel (fig. 23). They occurred at the latest from the fourth century B.C. onward, for instance at Doliana, in the quarries used for, among other things, the construction of the Temple of Athena Alea at Tegea,[103] and on the Pnyx in Athens.[104] Other examples have been noticed at Hellenistic Amathous.[105] Yet, the system most probably was already applied much earlier.[106] It doubtless was applied where the rock – be it marble as at Doliana or limestone as on the Pnyx and at Amathous – could split easily. When the stone finally split, this may not have been the result only of the swelling of the wedge after it had been soaked with water but also the result of the fact that the water could infiltrate into smaller cracks in the rock caused by cutting the wedge-holes. For this same reason, in the sandstone quarries of Spessart in Germany water was until quite recently used in combination with metal wedges.[107] In some cases water alone can be used to split off blocks. In some parts of northern Greece, people quarry stones during the winter simply by cutting holes that are then filled with water.[108] That creates ice wedges, whose power can be as strong as that of good metal wedges. At Doliana some cracks between never-used wedge-holes cut for wooden wedges may have been caused mainly by water, which froze in them during the winter (fig. 24).

Ancient Greek stone quarrying techniques, which the Greeks themselves to a large extent may have inherited from the Levant, developed very quickly into a powerful, highly sophisticated craft based upon empiric knowledge, the application of which could vary considerably, not so much because of chronological developments as because of the properties of each specific stone or even each layer. In this respect the skills of the quarryworker and his knowledge of the material he was dealing with may have been far more important than the instruments he was using. These skills were later transferred to the Romans, who would develop stone quarrying on a never-before-seen and never-repeated scale.

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Notes

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J. W. Shaw, "Minoan Architecture: Materials and Techniques," *ASAtene* 49, n.s. 23 (1971), pp. 7–75.

1 Our most sincere thanks go to the Turkish and Greek authorities for granting us permission to work in the quarries in 1985 and 1986.

2 For the results of this analysis, see the article by L. Moens, et al. elsewhere in this volume.

3 S. Weinberg, in *Kunst und Kultur der Kykladeninseln im 3. Jahrtausend v. Chr.*, Badisches Landesmuseum Karlsruhe, 1976 (catalogue by J. Thimme, et al.), p. 54.

4 P. Getz-Preziosi, in Thimme, et al. (note 3), p. 74; eadem, *Early Cycladic Sculpture: An Introduction* (Malibu, 1985), p. 57.

5 Getz-Preziosi, in Thimme, et al. (note 3), p. 74.

6 W. Stevenson Smith, *The Art and Architecture of Ancient Egypt*, rev. ed. with additions by W. Kelly Simpson. The Pelican History of Art (Harmondsworth, 1981), pp. 32–34; G. Roux, *Ancient Iraq* (Harmondsworth, 1966), p. 79.

7 W. B. Emery, *Archaic Egypt* (Harmondsworth, 1966), pp. 182–183.

8 H. Goedicke, "Some Remarks on Stone Quarrying in the Egyptian Middle Kingdom (2060–1786 B.C.)," *JARCE* 3 (1964), p. 43.

9 Stevenson Smith (note 6), pp. 54–59.

10 Compare Goedicke (note 8), p. 43. According to Röder, *Steinbruchgeschichte*, p. 551, approximately 100,000 cubic meters would have been extracted here during the Old Kingdom.

11 Klemm, pp. 31, 37, fig. 38.1.

12 Klemm, pp. 36–37, fig. 38.2–3.

13 According to A. Lucas, in J. R. Harris, ed., *Ancient Egyptian Materials and Industries* (London, 1962), p. 239; Röder, *Steinbruchgeschichte*, p. 523; Klemm, p. 36. Yet, other scholars believe that iron tools were already introduced during the eighth or seventh century B.C.: W. M. Flinders Petrie, *Tools and Weapons* (London, 1917), p. 41, pl. 13; idem, *Six Temples at Thebes* (London, 1897), p. 19, pl. 21; R. Engelbach, *The Aswan Obelisk* (London, 1922), p. 5; Nylander, p. 8, n. 8.

14 Klemm, pp. 36–37, fig. 38.4–5.

15 For instance, in the late Roman quarries of the Mareotis: J. Röder, "Die antiken Steinbrüche der Mareotis," *AA*, 1967, pp. 122, 124.

16 According to Klemm, p. 36. At Jebel Silsiteh M. Waelkens saw several examples of splitting of the blocks below by means of punchstrokes.

17 The method has been described in detail by Röder, *Steinbruchgeschichte*, pp. 479–484; Klemm, p. 36.

18 See S. Clarke and R. Engelbach, *Ancient Egyptian Masonry: The Building Craft* (Oxford, 1930), p. 27; T. Koželj, "Les carrières de marbre dans l'antiquité: Techniques et organisation," in *Marbres helléniques: De la carrière aux chef d'oeuvre*, Brussels, Crédit Communal, December–April 1988 (Brussels, 1987), pp. 29–30; J. Cl. Bessac, "L'Apogée antique de la pierre taillée," *Pour la Science* 117 (1987), p. 38.

19 Goedicke (note 8), pp. 43–48.

20 Röder, *Steinbruchgeschichte*, p. 471.

21 The oldest still-preserved one is that set up by Sesostris I in the Temple of Atum at Heliopolis. See Cl. Vandersleyen, *Das Alte Ägypten: Kunst und Kultur*. Vol. 17 of *Propyläen Kunstgeschichte* (Berlin, 1985), p. 160, pl. 57.

22 Thus A. Zuber, "Techniques du travail des pierres dures dans l'Ancienne Egypte," in *Techniques et Civilisations* (Paris, 1956), pp. 175, 200, pl. 35 (here the punch traces have been mistaken for those of a pick).

23 Thus Röder, *Steinbruchgeschichte*, p. 511.

24 Thus Klemm, p. 36.

25 Röder, *Steinbruchgeschichte*, p. 515, figs. 28a–b.

26 Ibid., pp. 516, 523–524 (iron wedges from the Ptolemaic period onward); Klemm, p. 36 (iron wedges not popular before the Roman period).

27 M. Pillet, "L'extraction du granit en Egypte à l'époque pharaonique," *BIFAO* 36 (1936–1937), p. 75; Zuber (note 22), pp. 198, 200–202; Nylander, p. 6.

28 By Röder, *Steinbruchgeschichte*, pp. 516–523, fig. 29.

29 Nylander, pp. 7–8 (some iron wedges of this period have been found by Flinders Petrie). Pillet (note 27), pp. 77–80, on less convincing grounds, assumes that the Egyptians at first used metal wedges of hardened copper alloys.

30 See Bessac (note 18), p. 7, n. 8.

31 Compare ibid., pp. 38–39.

32 See M. J. Becker, "Minoan Sources for Steatite and Other Stones Used for Vases and Artifacts: A Preliminary Report," *Delt* 30 (1975), p. 252; idem, "Soft-Stone Sources on Crete," *JFA* 3.1 (1976), pp. 361, 373–374.

33 Shaw, p. 30.

34 Compare ibid., pp. 42–43.

35 The only Minoan ammoudha, or sandstone quarries, that have been studied in detail are those at Mallia ("Point du Moulin," worked as early as 1900 B.C.), Pelekita (north of Kato Zakro, worked about 1700 B.C.), Mochlos (worked about 1700–1500 B.C.), and Ta Skaria (near Palaikastro, perhaps worked as early as MM III, or LM I at the latest). On those quarries, see J. S. Soles, "A Bronze Age Quarry in Eastern Crete," *JFA* 10 (1983), pp. 36–46 (with all other bibl.; J. Driessen, in J. A. MacGillivray, L. H. Sackett, et al., "An Archaeological Survey of the Roussolakos Area at Palaikastro," *BSA* 79 (1984), pp. 143–149. Other quarries still need further study. A list is published by Shaw, pp. 33–41; Driessen (see above), p. 143, n. 31; Dworakowska, pp. 80–81.

36 Compare Shaw, p. 34; Soles (note 35), p. 40.

37 See Driessen (note 35), p. 146.

38 For instance, at Mallia and in some sectors of the limestone quarries at Archanes.

39 Shaw, p. 32, fig. 22; Soles (note 35), pp. 37–38; Driessen (note 35), p. 146.

40 Shaw, p. 33; Driessen (note 35), p. 146, n. 36.

41 For a description and illustrations, see Shaw, pp. 33, 39, 48, figs. 36a–b and 37 (top middle).

42 Shaw, p. 34; Driessen (note 35), p. 146.

43 See Soles (note 35), p. 40.

44 See Dworakowska, pp. 82–83.

45 See R. Gnoli, *Marmora Romana* (Rome, 1971), pp. 116, 161–162.

46 K. Bittel, "Vorläufiger Bericht über die Ausgrabungen in Boğazköy 1935: Hethitische Steingewinnung," *MDOG* 74 (1936), pp. 57–62; idem, *Die Ruinen von Boğazköy* (Berlin and Leipzig, 1937), p. 44; R. Naumann, *Architektur Kleinasiens von ihren Anfängen bis zum Ende der hethitischen Zeit*, 2nd ed. (Tübingen, 1971), pp. 38–42; U. Bahadir Alkım. *Yeşemek taşocağı ve heykel atelyesinde yapılan kazı ve araştırmaları.* Türk Tarih Kurumu Yayınları 5. Seri-Sa 32 (Ankara, 1974), pp. 1–13, pls. 1–3.

47 P. Neve, "Zur sogenannten Hethitischen Brücke in Hattuscha-Boğazköy," in *Festschrift E. Akurgal*, Anadolu (Anatolia) 21 (1978–1980), p. 69.

48 This evidence was checked on the spot by M. Waelkens.

49 The oldest stonemason's tools made of iron thus far discovered were in Sargon's palace at Khorsabad. See Bessac (note 18), p. 41.

50 See, for instance, J. B. Ward-Perkins, "Quarrying in Antiquity: Technology, Tradition and Social Change," *Proceedings of the British Academy* 57 (1971), p. 143. This theory is mainly based upon the idea that Archaic Greek sculpture also borrowed a grid system from Egypt, which was already applied in the quarry.

51 See J. Boardman, *Greek Sculpture: The Archaic Period* (New York and Toronto, 1978), p. 11.

52 Ibid., pp. 13–15.

53 See ibid., p. 23.

54 See J. Griffiths Pedley, *Greek Sculpture of the Archaic Period: The Island Workshops* (Mainz, 1976), p. 19, no. 1; p. 21, no. 3; pls. 1 and 2b–c.

55 F. W. Hamdorf, "Lakonische Perirrhanteria," *AthMitt* 89 (1974), pp. 47–64; Boardman (note 51), p. 25; O. Palagia, "Les techniques de la sculpture grecque sur marbre," in *Marbres helléniques* (note 18), p. 77, n. 4.

56 Compare Boardman (note 51), pp. 18–23; Pedley (note 54), p. 11 (with bibl. on the much-debated origin of monumental Greek sculpture); Palagia (note 55), p. 77, n. 1.

57 Most probably the quarries at Phlerio and Apollonas on Naxos, whose unfinished colossal statues are dated between the late seventh (almost certainly too early) and the early fifth centuries (too late) B.C. An early sixth-century B.C. date is more likely. See: Dworakowska, p. 132; Pedley (note 54), p. 18; P. Karakatsanis, *Studien zu archaischen Kolossalwerken.* European University Studies, ser. 38, Archaeology, vol. 9 (Frankfurt, Bern, and New York, 1986), pp. 63–64; Palagia (note 55), p. 80.

58 See R. Martin, "Le marbre dans l'architecture grecque," *BMusArt* 53.2 (1982), p. 10.

59 For Greece this certainly applies to Naxos, Paros, Samos, Thasos, Doliana, the Pentelic quarries, and perhaps even Mount Hymettos. See: R. Martin, *Manuel d'architecture grecque*, vol. 1. *Matériaux et techniques* (Paris, 1965), pp. 137–142; Dworakowska, pp. 86–88; Pedley (note 54), pp. 18–29, 38–41, 45–51; J. P. Sodini, A. Lambraki, and T. Koželj, "Les carrières de marbre à l'époque paléochrétienne," in J. Servais, ed., *Aliki*, vol. 1. *Les deux sanctuaires.* Vol. 9 of *Etudes Thasiennes* (Paris, 1980), p. 5. For the oldest stone material used in Athenian architecture, see R. E. Wycherley, "The Stones of Athens," *Greece and Rome*, 2nd ser., vol. 21 (1974), pp. 54–67.

60 In Asia Minor there was already some activity at Belevi, the Prokonnesos, some quarries near Uşak, on the territory of Dorylaeion, and probably also at Miletos and Herakleia on the Latmos. See Martin (note 59), pp. 142–143; Dworakowska, pp. 88; Pedley (note 54), pp. 57–59; D. Monna and P. Pensabene, *Marmi dell'Asia Minore* (Rome, 1977), pp. 124, 131–137; S. Walker, "The Marble Quarries of Proconnesos: Isotopic Evidence for the Age of the Quarries and for *Lenos*-sarcophagi Carved at Rome," *StMisc* 26 (1981–1983), pp. 57–59; E. Pfuhl and H. Möbius, *Die ostgriechischen Grabreliefs*, vol. 1 (Mainz, 1977), p. 8, no. 2, pl. I (red-veined marble from Dorylaeion, probably quarried at Süpren); M. Waelkens, *Die kleinasiatischen Türsteine* (Mainz, 1986), pp. 37, no. 9, pl. I (perhaps from the Selvioğlu quarries).

61 W. Alzinger, "Ritzzeichnungen in den Marmorbrüchen on Ephesos," *ÖJh* 48 (1966–1967), pp. 61–72.

62 Some quarries of this type can still be seen on Mount Hymettos. Others have been noticed on Aegina (dated to the early fifth century B.C.), and on the Pnyx (dated to the early fourth century). See: W. Wurster, "Antike Steinbrüche an der westlichen Nordküste Aeginas," *AA*, 1969, p. 20, figs. 2, 4, 7; K. Kourouniotes and H. A. Thompson, "The Pnyx in Athens," *Hesperia* 1 (1932), p. 139, figs. 23b–c.

63 Good examples are the fifth-century B.C. quarries at Agrileza, where the marble for Sounion was quarried. See G. R. Lepsius, *Griechische Marmorstudien* (Berlin, 1892), pp. 28–29. Some of the fourth-century B.C. quarries of gray limestone, serving Delphi, belong to the same type: P. Amandry, "Chronique Delphique, VI: Les carrières," *BCH* 105 (1982), p. 714.

64 See Alzinger's richly illustrated article, mentioned in note 61.

65 For the Piraeus quarries, see Xen. *Hell.* 1.2,4; for Syracuse, see Thuc. VII.86,1, VII.87; Cic., *Verr.* V.27,68; J. Charbonneaux, R. Martin, and F. Villard, *Archaic Greek Art: 620–480 B.C.* (London, 1971), p. 180, fig. 219. Other large quarries occurred near the theater at Delos: L. Cayeux, *Description physique de l'île de Délos.* Vol. 4 of *Etudes Déliennes* (Paris, 1911), p. 9, fig. 5.

66 D. Berranger, "Le relief inscrit en l'honneur des Nymphes dans les carrières de Paros," *REA* 85 (1983), pp. 235–257. The quarries of Syracuse, mentioned in note 65, are also partly underground.

67 These traces have been described by Ward-Perkins (note 50), p. 138, pl. Ib; J. Röder, *Marmor Phrygium: Die antiken Marmorbrüche von Iscehisar in Westanatolien. JdI* 86 (1971), pp. 298–299, figs. 48–49; Alzinger (note 61), p. 63, figs. 35–37 ("langstielige Hacke"); S. Kasper, "Der Tumulus von Belevi (Grabungsbericht)," *ÖJh* 51, Beiblatt (1976–1977), p. 170, figs. 14–15 ("Spitzhacke"); E. Dolci, *Carrara: Cave antiche: Materiali Archeologici* (Commune di Carrara, 1980), passim (identified as a "scolpello," a "subbia," or a "piccone"); A. Dworakowska, *Quarries in Roman Provinces.* Vol. 16 of *Bibliotheca Antiqua* (Warsaw, 1983), pp. 146–147.

68 A somewhat related pick has been illustrated by Alzinger (note 61), p. 65, fig. 34. I cannot agree with Koželj (note 18), p. 23, according to whom the Greeks would have used a pick with one pointed and one bladed edge ("polka") for softer stones, and another with double-pointed edges, set on a short handle ("smille"), for harder stones. In fact, the quarry traces do not reflect these different tools.

69 See Bessac (note 18), p. 37, fig. 1.1.

70 Röder, *Tuffsteinbrüche*, p. 255, pl. 21.2.

71 Ibid., p. 255.

72 Ibid., p. 255, fig. 6; Dworakowska (note 67), p. 60, figs. 3, 4.

73 A. Dworakowska, "Greek Quarrying Hammers as Shown in Ancient Texts," *Archaeologia* 25 (1974), pp. 22–23; Dworakowska, p. 118.

74 Ward-Perkins (note 50), p. 138, pl. Ib, wrongly assumed that these types of traces were characteristic of compact stones, such as marble only.

75 See Alzinger (note 61), pp. 61–74, figs. 33, 37–39; Kasper (note 67), p. 158, fig. 14.

76 Amandry (note 63), p. 714, fig. 34.

77 Ward-Perkins (note 50), p. 138, pl. VIIb (there wrongly identified as being characteristic of softer stones); Röder (note 67), p. 298, fig. 47; A. Peschlow-Bindokat, "Die Steinbrüche von Milet und Herakleia am Latmos," *JdI* 96 (1981), pp. 175, 179, 182, 193, 209, figs. 26, 35–36, 39, 61, 85; Dolci (note 67), pp. 146–148, 152–154, 170 (wrongly identified as traces of a "scalpello").

78 See, for instance, Röder (note 67), p. 298, fig. 47; N. Asgari, "Roman and Early Byzantine Marble Quarries of Proconnesus," in *10. International Congress of Classical Archaeology, Ankara-Izmir 1973* (Ankara, 1978), pl. 139, fig. 10.1; Sodini, Lambraki, and Koželj (note 59), p. 41, fig. 81. Its ancient name is uncertain, although the instrument may have corresponded to the "tykos" of antiquity, even if it does not fit completely the description of this tool by Dworakowska (note 73), pp. 23–24.

79 For instance, Röder, *Tuffsteinbrüche*, p. 232, fig. 5.1; Dworakowska, p. 146; eadem (note 67), p. 75, fig. 1.1, pp. 79, 80, fig. 3.1–3, p. 81; G. Daux, "Chronique des fouilles 1961," *BCH* 86 (1982), p. 879, fig. 4.

80 Compare Röder, *Tuffsteinbrüche*, p. 256; Dworakowska (note 67), p. 148.

81 The change in fact may have occurred sometime during the Flavian period, at least in Asia Minor. An Imperially owned and exploited marble quarry at Altintaş (Ibrıklık) in the Upper Tembris Valley thus seems to have been worked with the lighter pick in its upper section, whereas, after the reorganization of the exploitation system, dated by inscriptions to the reign of Domitian, the quarrymen shifted toward the heavier type of pick. In most other Imperially owned quarries, exploited by the Imperial administration from the first century A.D. onward, we also noticed traces of the lighter pick in the upper levels, and those made by the heavier pick in all lower parts of the quarry. Similar traces also occur in the quarry known as "The Rods of Digenis" on Crete, which in my opinion must have been Roman, not late Classical as was assumed by the publishers: M. K. Durkin and C. J. Lister, "The Rods of Digenis: An Ancient Marble Quarry in Eastern Crete," *BSA* 78 (1983), p. 74.

82 Traces of a handpick and a chisel can be seen on a rock-cut stadium wall at Delphi: T. Koželj, "An Example of Cutting Marble Using a Handpick and a Chisel," *StMisc* 26 (1981–1983), pp. 127–134. Some scattered punch marks, mainly on spots where one seems to have corrected outward-moving quarry sections, occur in the Hymettian and in the Pentelic quarries. See also Sodini, Lambraki, and Koželj (note 59), p. 28, fig. 50; p. 42.

83 Th. Kraus and J. Röder, "Voruntersuchungen am Mons Claudianus im März 1961," *AA* 1962, pp. 723–724, figs. 18–20; Röder, *Steinbruchgeschichte*, pp. 516–528, 533, fig. 29.

84 Nylander, pp. 8–10; Kasper (note 67), pp. 170–172.

85 Röder (note 67), pp. 298, 300.

86 In Roman Gaul, for instance, they appear to have had very standardized dimensions. See R. Bedon, *Les carrières et les carriers de la Gaule Romaine* (Paris, 1984), p. 103.

87 Compare Dworakowska, pp. 131–135.

88 This description is based upon our own research on the spot. See also: W. Koenigs, "Beobachtungen zur Steintechnik am Apollon-Tempel von Naxos," *AA* 1972, pp. 381–382.

89 See Koželj (note 18), p. 29, fig. 9a.

90 Kasper (note 67), pp. 170–172, figs. 16–17.

91 Nylander, p. 9.

92 Wurster (note 62), p. 30, n. 15.

93 G. Touchais, "Chronique des fouilles en 1977," *BCH* 102 (1978), p. 660.

94 Amandry (note 63), p. 717, fig. 35.

95 Sodini, Lambraki, and Koželj (note 59), pp. 42–43; Koželj (note 18), p. 26. The examples cited here are rather late (Aliki, Aswan, St. Boil).

96 For a description of the technique, see Röder, *Tuffsteinbrüche*, p. 265; idem, *Steinbruchgeschichte*, p. 517, fig. 29.9; pp. 523, 536 (wrongly dated to late antiquity). This technique was wrongly explained by Durkin and Lister (note 81), p. 74, as a "forerunner" of the usual wedging technique.

97 See Kasper (note 67), pp. 172–173.

98 A. Lambraki, "Les roches vertes: Etude sur les marbres de la Grèce exploités aux époques romaines et paléochrétiennes" (Ph.D. diss., Paris, Sorbonne, 1978), p. 81. I thank Mrs. Lambraki for having provided me with a copy of her wonderful dissertation.

99 See also Röder, *Tuffsteinbrüche*, pp. 265–266; idem, *Steinbruchgeschichte*, pp. 524–528. Röder considered this technique as belonging to the Imperial period.

100 Nylander, p. 9.

101 See, for instance, Dolci (note 67), p. 164 (dimensions: 35 × 40 cm).

102 Lambraki (note 98), p. 227, even mentions an early Christian wooden wedge, found at Chassambali, whose dimensions were 60 × 60 cm.

103 Here the wedge-holes are between 15 and 30 cm long and have a depth of 10 to 16 cm.

104 See the discussion in Durkin and Lister (note 81), p. 82 (dimensions: 15 × 18 cm).

105 Koželj (note 18), p. 26 (dimensions: 20 × 20 cm).

106 According to G. Nenci, "Le cave di Cusa," *AnnPisa*, Classe di Lettere e Filosofia, ser. 3, vol. 9.4 (1979), p. 142, wooden wedges would have been used during the sixth and fifth centuries B.C. to split off the column drums in the quarries of Selinunte.

107 Wurster (note 62), p. 30, n. 15.

108 See Lambraki (note 98), p. 227.

Thasos and the Ancient Marble Trade: Evidence from American Museums

John J. Herrmann, Jr.

It has long been known that marble and other hard stones were shipped over great distances in antiquity. Ancient authors allude to these operations, and mute testimony has come from the stockpiles of rough blocks imported from a multitude of Imperial quarries and deposited on the banks of the Tiber.[1] Over the last twenty-five years, however, archaeologists have greatly improved their understanding of this flow of materials. Many of the long-known quarries of colored marble have been explored, and others have been rediscovered in Egypt, North Africa, Asia Minor, and Greece. Good color plates in books, such as that of Raniero Gnoli, have made these stones much more widely known.[2] Much progress has also come through the study of types and workmanship rather than materials. Standardized sculpted marble products such as column capitals and sarcophagi have been observed around the Roman world and retraced to their lands of origin.[3]

The procedures for transmitting these products have been inferred from partly finished pieces and from marble recovered from Roman shipwrecks. These procedures appear to have undergone some change over the course of the centuries; practical experience would accumulate, and the relationship between quarry, quarrymen, and sculptors could be altered according to varying circumstances, either in the quarrying area or at the final destination.[4] In Archaic and Classical times, a good deal of the shaping of a statue was done in the quarry. Not only would the weight of the block be reduced but flaws that might lead to breakage would appear. Sculptors may frequently have traveled from the quarry area to finish the work at its destination.[5] Republican shipwrecks, like those from Antikythera and Cape Mahdia, on the other hand, carried statuary and architectural elements that were essentially finished.[6]

In Imperial times,[7] cargoes tended to be raw blocks that would be sculpted at their destination, either by local artisans or by itinerant craftsmen, who on occasion came from the areas where the blocks were quarried.[8] In the case of special stones, however – such as purple porphyry from Egypt or violet and white *pavonazzetto* from the quarries at Dokimeion in Asia Minor – architectural ornament and statuary could be sent in a fairly complete state from the quarry.[9] By the third century A.D., some relatively standardized marble products, such as sarcophagi and capitals, were frequently exported from the quarry in a schematic state; that is, they were cut down to their approximate final shape in order to reduce the weight of a shipment. The last stage of work, on the other hand, was postponed to reduce the risk of damage in transit. Many of these schematic products are quite distinctive; the various quarrying areas of Asia Minor, for example, each produced slightly different forms of a schematic garland sarcophagi, which has helped to map the areas of their diffusion.[10]

Among the famous quarries of antiquity, those on the island of Thasos in the north Aegean remain relatively little known as a source for overseas activity. Literary sources such as Pliny, Seneca, and Pausanias, as well as Diocletian's *Edict on Maximum Prices*, make it clear that Thasos was an exporter of marble for sculptural purposes in Greek and Roman times.[11] Putting flesh on these literary bones, however, has been a slow process. To be sure, the very extensive quarries at Aliki[12] and the many smaller quarries elsewhere along the east coast of the island strongly confirm the importance of the quarrying activity there. On the other hand, it is not generally maintained that Thasos was the home of a major school of sculpture, and no signatures of Thasian sculptors abroad are known.

Manifestations of Thasian exportation have, however, begun to be isolated. Recently it became clear that Thasos was one of the places that provided sarcophagi for Rome. Unfinished sarcophagi with round ends have been found in the quarries of the Saliari region. Since round-ended marble coffins were used only in the area around Rome, the blanks on Thasos must have been prepared with this market in mind. The two protuberances on the long sides of these schematic sarcophagi were usually converted into the heads of lions.[13] The transport of this kind of quarry-rough product has been vividly illustrated by a shipwreck off San Pietro on the Italian coast near Taranto; round-ended marble tubs with protuberances were found together with rectangular tubs. The marble of the San Pietro wreck, unfortunately, has not been identified, and the unfinished coffins in this cargo could have been produced by quarries other than those on Thasos.

Unmistakably Thasian marble products have rarely been identified outside the island. One exception to this rule is very late: simple schematic Ionic capitals of the third and fourth centuries with an unusual tendril in their volute channels. Such capitals were used in the churches by the quarries at Aliki and were diffused from Aliki as far as Italy and Syria.[14] While these capitals were exported prefabricated, a closely related product shows that Thasian architectural

FIG. 1

Archaic head from a relief. Harvard University, Arthur M. Sackler Museum, gift of Mr. and Mrs. Norbert Schimmel 1969.175. Photo: The Harvard University Art Museums.

FIG. 2

Archaic stele with seated woman. Thasos, Archaeological Museum 8. Photo: Ecole française d'Athènes, neg. 31182.

sculptors also traveled in person to Italy in the first half of the third century. Two composite capitals found at Baia in Campania mix features of the Thasian Ionic capitals with elements drawn from the local Italian environment.[15]

This identification of Thasian architectural decoration in Italy was made on the basis of typology, but it was reinforced by an examination of the material. Comparison with chips from the Aliki quarry made the origin of the Ionic and composite capitals doubly clear. As is commonly acknowledged, Thasian marble has a distinctive appearance, and under the right conditions (such as a fresh break) may not even require the presence of a quarry sample for secure recognition.[16] The stone has unusually large grains, which under favorable circumstances reflect back light almost like flakes of new-fallen snow. In breaks, moreover, the marble has a loose texture. This relatively characterful structure, it might be added, makes the stone less than an ideal material for sculpture.

Some exported Thasian marble has been identified purely on its appearance. The reports of the New York University expedition to Samothrace have affirmed that Thasian marble was regularly used there for architecture and inscriptions and at least occasionally for statuary.[17] The idea seems eminently plausible given the proximity of the two islands. It might be added that Thasos undoubtedly had a role in the nearby regions to its west as well as to its east. The marble of the Arch of Galerius at Thessaloniki seems almost certain to be from Aliki on the basis of its appearance.[18] John Ward-Perkins has identified the material of two sarcophagi found in Rome, now in the Walters Art Gallery, as Thasian. The figural decoration was certainly executed by workshops based in Rome, but Ward-Perkins has pointed out how the carving was affected by the coarse grain of the marble.[19] Amanda Claridge has tentatively identified an unfinished bust of

FIG. 3

Head of Aphrodite from the "Ludovisi Throne." Rome, Museo Nazionale Romano 8570. Photo: Hirmer Verlag, Munich.

Euboleus at Athens as Thasian marble and noted how the preliminary techniques used in the piece differ from those customary in Athens.[20]

Recently, sophisticated technologies have been exploited to recognize a number of sculptures made of the marble of Aliki at Cyrene. Analyzing the isotopes of carbon and oxygen, Herz, Kane, and Hayes determined that fully eleven percent of the sculptures tested at the sanctuary of Demeter and Kore were of Thasian marble.[21] The sculpture from the site is in the course of publication, and I have come across an illustration of only one of these Thasian pieces: a typically Italic togatus.[22] Since the togati found on Thasos lack the deep folds and umbo of this statue,[23] it seems likely that the marble for the North African statue was sent from the Aliki quarry as an unworked block.

The marble of the Saliari region, which terminates in Cape Vathy, deserves separate attention from that found elsewhere on Thasos. It happens to be whiter and slightly finer-grained than the grayish marble of Aliki, probably making it better suited for sculpture; this relative desirability is attested by the modern quarrying operations at Vathy, which produce both blocks and powder for plaster. More relevant for our purposes is the fact that the marble of the Saliari

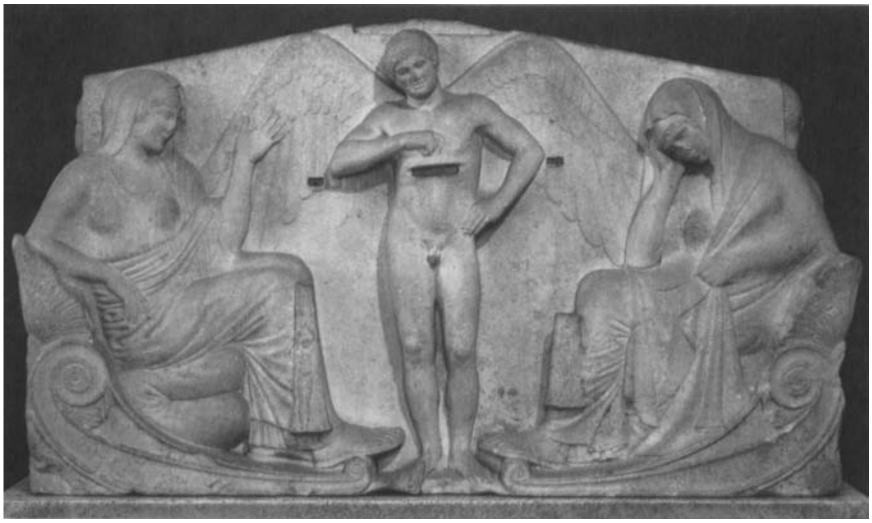


FIG. 4

Three-sided relief. Boston, Museum of Fine Arts, H. L. Pierce Fund 08.205. Photo: Museum of Fine Arts.

area has a rather distinctive chemical property; it consists essentially of the mineral dolomite (calcium magnesium carbonate). As was pointed out by William Young some twenty-two years ago, and amply confirmed and elaborated recently by Herz and by Cordischi, Monna, and Segre, dolomitic marble is highly unusual among the principal marbles of antiquity. The marbles of Aliki and all other known exporting quarries throughout the ancient Mediterranean consist primarily of the mineral calcite (calcium carbonate).[24]

The rarity of dolomitic marble in ancient sculpture suggested a simple test. Over the years it had appeared to me and to other scholars that a fair number of sculptures in museums in the United States were made of the marble of Thasos.[25] It seemed reasonable therefore that if one of these Thasian-looking sculptures proved to be dolomitic, it probably came from the Saliari region. As was pointed out to me by Richard Newman, the technique of X-ray diffraction readily distinguishes between dolomite and calcite, and the test can be carried out on a very small quantity of powder – the equivalent essentially of one shake from a salt shaker. It furthermore employs technology available in the laboratories of many American museums.[26]

The first results came from the Cleveland Museum of Art, where in tests conducted by Bruce Christman five sculptures that appeared Thasian all proved to be made of dolomite. It was determined by Newman that a suspected Thasian piece on loan to the Yale University Art Gallery was dolomite. Subsequently Norman Herz judged the piece to have a ninety-nine percent chance of coming from the quarries around Cape Vathy on the basis of its isotopes of carbon and oxygen.[27] A candidate in the Fogg Art Museum in Cambridge, Massachusetts, had previously been shown to be dolomitic marble by Farrell, Stodulski, and Donahue.

Encouraged by such preliminary successes, a program of sampling sculptures in the Boston area was carried out by

FIG. 5a

Severe Style head of a youth. Right side. The Cleveland Museum of Art, J. H. Wade Fund 28.195. Photos: The Cleveland Museum of Art.

FIG. 5b

Front of Severe Style head, figure 5a.

Richard Newman. The pieces chosen were not simply obvious cases of Thasian marble. Many marginal situations in which the granular structure and color were largely obscured by heavy patination or by various kinds of severe weathering were examined as well. The objective was to determine the extent of the Thasian presence as fully as possible rather than to produce the highest success rate. Scrapings were taken from breaks of pieces in the Museum of Fine Arts, the Isabella Stewart Gardner Museum, and the Harvard University Art Museums. Out of forty-eight sculptures tested, twenty-five proved to be dolomitic, and twenty-three calcitic. Of the total of catalogued marble sculptures in the two former museums (ISG 71, MFA 413 = 484; 19 of them dolomitic), 3.9 percent can be considered almost certainly Thasian, from the quarries in and around Vathy. The calcitic marbles, it should be noted, are not necessarily non-Thasian; some of them may simply be from some other quarry on the island, most likely that at Aliki.

These sculptures in coarse-grained dolomitic marble will be reviewed briefly, keeping in mind the question, whether there is a component of Thasian worksmanship involved. Was the marble sent out as crude blocks to be worked by others, or did sculptors from the island provide the finishing? Another possibility to consider is whether figural sculptures were exported in a semi-finished or schematic state, as were architectural decoration and sarcophagi. A case for a Thasian cultural as well as physical contribution will be presented.

An Archaic head from a relief in the Harvard University Art Museums is carved in an eccentric Ionian style that might well be traceable to the same source as its dolomitic marble (fig. 1). The head, which was broken from an unfinished relief, is said to come from Turkey,[28] but it has much in common with a stele on Thasos (fig. 2).[29]

FIG. 6a

Head of Persephone(?) from Assos. Front. Boston, Museum of Fine Arts, gift of the Archaeological Institute of America 84.64. Photo: author.

FIG. 6b

Left side of head of Persephone, figure 6a. Photo: author.

Broad, low skulls, horizontal eyebrows, and pursed lips appear in both. The indefinite modeling is also comparable. Thasos is not thought to have had a school of its own in Archaic times; Thasian works are considered derivative of the Parian school with influences from Asia Minor.[30] Thasos, however, may have had a role on the northern frontier of the Greek world in the realm of marble sculpture comparable to its influence in the realm of coinage.[31]

The Getty kouros is another work of the Archaic period executed, as has previously been determined, in Thasian marble.[32] Its provenance is unknown, but it would be most natural to suppose that it had been commissioned for a site in the north Aegean. Since the style seems alien to Thasos, the artist could have been a migrant from the south. On analogy with the following cases, on the other hand, it is also possible that the stone was exported either partly shaped or even as a rough block, perhaps to a destination in the West.

A group of heads, hands, and feet from two akrolithic statues apparently of the second half of the sixth century B.C. on loan to the J. Paul Getty Museum[33] are probably in the marble of the Saliari area. While it has not been possible to have them tested, the origin of their marble could hardly be more evident on the basis of visual inspection. These akrolithic attachments are reported to be from Morgantina, Sicily, and their economic use of material tends to confirm the idea that they come from a region such as Sicily or South Italy that lacked indigenous sources of marble.

During the period of the Severe Style, Thasian marble almost certainly turned up in this remote Italian setting. It has long been known that both the so-called Ludovisi Throne in Rome (fig. 3) and the similar three-sided relief in Boston (fig. 4) are coarse-grained dolomitic marble, presumably from the Saliari area.[34] The two are generally thought to have been made in relationship to one another by two different sculptors working in South Italy.[35] These sculptures have already been put in relation to the northeastern Greek world by Ernst Langlotz simply on the basis of their style.[36] To this group can now be added a Severe Style head in Cleveland, which likewise has an Italian provenance and is also made of coarse-grained dolomite (figs. 5a–b).[37] Brunilde Ridgway has singled out the flat rendering of the hair with finely engraved lines alternating with deeper ones as a feature that links the head to the bronze youth from Castelvetrano in Sicily.[38] A kindred treatment appears in the Aphrodite from the Ludovisi Throne (fig. 3),[39] and while the Cleveland head has a drier, more graphic technique, the common approach tends to strengthen the link between the two pieces. This group of fifth-century sculptures from Italy carved in dolomitic stone may well be extended by the charioteer from Motya, which is also reportedly in Thasian marble.[40]

During the rest of the Classical and most of the Hellenistic period, the dispersion of Thasian marble seems generally to have been limited to the north Aegean. A strong stimulus for sculptural activity there came with the presence of Skopas of Paros on Samothrace and Thasos itself.[41] Fine Hellenistic statuary has been found in the area, and Andreas Linfert has centered this phenomenon on Thasos.[42] Linfert also hypothesizes a strong Thasian influence on distant Cyrene,[43] a view that seems supported by the recent isotopic identifications of marble from Aliki there.[44]

A severely eroded female head of dolomite in the Museum of Fine Arts, Boston, was excavated at Assos on the coast of the Troad opposite Lesbos (figs. 6a–b).[45] The fragment has been dated to the late Hellenistic or early Imperial period since it was found near the tomb of Publius Varius Aquila. This reappearance of Thasian marble can be considered a regional phenomenon; by sea, Assos is actually closer to Thasos than most of Macedonia is. The head could well be from a figure of Persephone; it has much in common with one of the Grimani statuettes in Venice: the "Abbondanza"–a minor work probably carved by an Attic sculptor around 420 B.C. (fig. 7).[46] The similarity seems to be more than typological; the Assos head could as well be an original of the Classical period as a Roman copy of one. Not only is the hairstyle the same (insofar as it is preserved), but the carving of the locks is comparable, and both figures have a somewhat squarish jawline. Its slender proportions, which would not be out of place in the late fifth century,[47] give the head from Assos a distinctive character. Technically, the fragment also recalls fourth-century sculpture on Thasos. The very shallow carving, noticeable particularly in the eyes and hair, and the

FIG. 7

Head of a statue of Persephone (the so-called Abbondanza). Venice, Museo Archeologico 106. Photo: DAI Rome.

FIG. 8

Helmeted head, fourth century B.C. Thasos, Archaeological Museum 26. Photo: Ecole française d'Athènes.

FIG. 9a

Head of a young man. Front. Harvard University, Arthur M. Sackler Museum, gift of Paul J. Sachs 1922.171. Photos: The Harvard University Art Museums.

FIG. 9b

Left side of head of young man, figure 9a.

rough surface – probably not entirely due to the poor state of preservation – can be paralleled in the head of Pan and, above all, in the helmeted head, both in the Thasos Museum (fig. 8).[48] The piece from Assos could well be another Classical repetition of the Grimani Kore type, in this case, probably from around 400 B.C. Since there are no close parallels datable in the late fifth century on Thasos itself, it is necessary to leave open the question of the sculptor's origin; an artist from Athens present in the Troad could have made use of the imported material, even though a carver from Thasos would have been more comfortable with it.

A head of an athletic-looking young man of unknown provenance in the Harvard University Art Museums has recently been published as a forgery by Karina Türr (figs. 9a–b).[49] In a forthcoming catalogue, Cornelius Vermeule defends the head as a work of around A.D. 50, calling attention to its Thasian marble,[50] an observation confirmed by the dolomitic nature of the stone. The peculiar style as well as the unusual material may also be explained by its Thasian connections. A parallel can be found in an over-life-size head of Alexander recently excavated on Thasos (fig. 10).[51] In both, the features have a full, compact modeling and are outlined in a limpidly clear way. A notable similarity can also be seen in the hair, whose turbulent, yet almost prismatically defined locks are striated with sharp, V-shaped grooves. The effect is reduced in the Harvard head since many of the locks have only been blocked out. The prototype for the Harvard youth may well have been Hellenistic, as was that of the Thasian Alexander;[52] the way the hair is brushed across the forehead from a division at the side and the rather elongated but fleshy face recall the bronze Hellenistic ruler in the Museo Nazionale Romano (fig. 11).[53] The Harvard head then has enough in common with a find on the island to suggest that its sculptor was a Thasian, and he may well have been working in the north Aegean.

With the Roman domination, and especially with the Roman Imperial period, central Italy became a significant consumer of Thasian marble. One of the earlier dolomitic sculptures in Boston with a reputed Italian provenance is a head of Polyphemos, which could be either late Hellenistic or early Imperial in date (fig. 12).[54] In spite of the more open, mobile, high-baroque composition of this piece, there are certain echoes of the recently found Alexander (fig. 10); the robust locks of hair have somewhat similar, sharply chiseled striations. The monster could have been carved by an emigrant from the island, but the stylistic evidence is not yet strong enough to provide firm support for the suggestion provided by the material.

Several sculptures in Thasian marble stemming from Italy are copies of or variations on Classical prototypes. All of them seem to be typical products of accomplished sculptors operating near the Imperial capital, and on the basis of the workmanship, there is little reason to think that these artists were from Thasos. Thasos clearly contributed to the vast stockpiles of marble blocks accumulated at Rome in the first 150 years of the Imperial period.[55] A Polykleitan head of Hermes from Capua, now in Boston, is typical of high-quality work of the early Julio-Claudian period; features are outlined and locks are striated in a way that reflects the bronze original.[56] A fine torso in Thasian marble in the Gardner Museum has a Classical squareness of proportion and an elegantly modulated surface.[57] The "Nelson Head" in the Museum of Fine Arts is an eclectic composition executed with drillwork typical of second-century Italy.[58] An ideal head of a woman in Cleveland (fig. 13)[59] is a copy of or a variation on a Severe Style original.[60] Its bland, simplified modeling and heavy-lidded eyes are much like those of copies of fifth-century works from Hadrian's Villa.[61]

In at least a few sculptures of dolomitic marble probably or certainly stemming from Rome, on the other hand, there does seem to be a Thasian component to the workmanship, and these sculptures could well have been made by artists from the island active in central Italy. A magnificent female portrait with a crest of loose locks of hair in the Museum of Fine Arts is carved in the marble of Vathy (figs. 14a–c).[62] The sculptor has exploited the grainy, loose quality of the material to impart a special fluffy lightness to the hair and a sensitive fleshiness to the face. The head, which was formerly considered Flavian but has recently been dated to the Hadrianic period by Zanker,[63] was purchased in Rome, and its illusionistic mobility seems fully in the

FIG. 10

Head of Alexander. Thasos, Archaeological Museum 3719. Photo: Ecole française d'Athènes, neg. R 2327,12.

FIG. 11

Head of Hellenistic bronze portrait statue. Rome, Museo Nazionale Romano 1049. Photo: Alinari/Art Resource, N.Y.

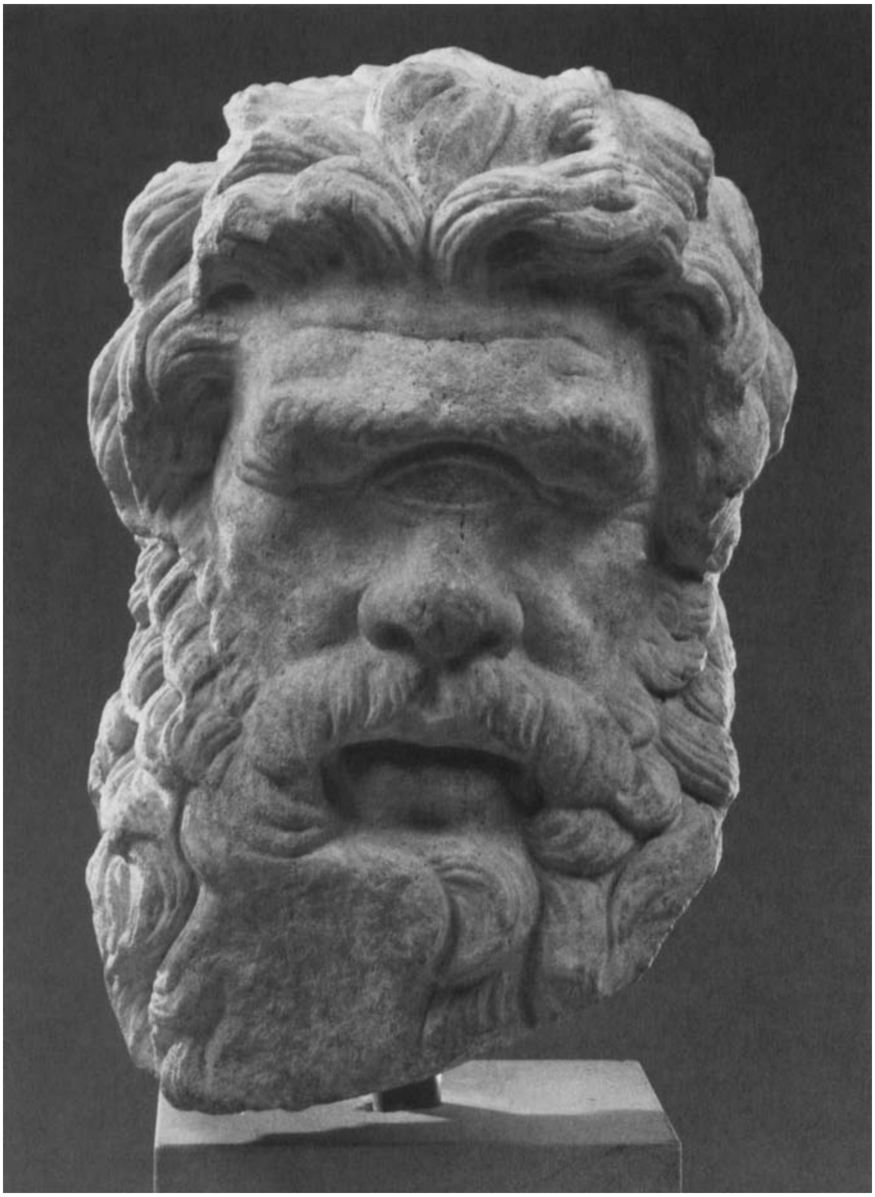


FIG. 12

Head of Polyphemos. Boston, Museum of Fine Arts, in honor of Edward W. Forbes from his friends 63.120. Photo: Museum of Fine Arts.

Italian tradition. There are, however, certain anomalies in terms of that tradition. The bun at the back of the head is not the customary coil of braids but instead is an unstable cluster of large curls, which in places are arbitrarily outlined and split with deep drill channels.[64] The surface of these locks, moreover, is articulated with broad, sharply defined grooves unlike the softer, finer texturing typical of second-century Rome.

A similar stylization of hair is seen in a colossal head of Hadrian from the Caseggiato del Serapide at Ostia (figs. 15a–b)[65]; the heavy curls are carefully grooved and at times outlined with the drill. A comparison between the curls on the neck of the Hadrian (fig. 15b) and the rear view of the lady's bun (fig. 14c) is particularly striking. Zanker has also noted a relationship between the two works.[66] Because of the schematic approach that dominates the Ostian Hadrian, Raissa Calza has ascribed the head to an artist from the East. The material, which is said to be a fine-grained Greek marble ("marmo greco levigato a grana fine"), is not likely to be from Thasos, yet among Calza's comparisons for the style of the piece is the statue of Hadrian from the Agora of Thasos (fig. 16).[67] Indeed, the modeling, with long undulating furrows, as well as the generalized likeness, tend to link the two images of the emperor. While presenting a greater mobility in its front view, the female portrait in Boston echoes the same provincial matrix in its treatment of hair. This relationship with a Thasian statue combined with marble from the island makes it likely that the sculptor of the Boston lady came from Thasos. The Hadrian from Ostia could also have been made by a Thasian – this time working in a different material – or perhaps by another easterner active in the same workshop.

FIG. 13

Roman Severe Style head of a girl. The Cleveland Museum of Art, gift of Mrs. Leonard C. Hanna, Jr. 24.125. Photo: Cleveland Museum of Art.

Another portrait made of dolomite in Boston, this time of a short-bearded man (fig. 17),[68] belongs to this group, and it too could have been carved by a Thasian active in Rome. The head, dated around A.D. 140, has undulating, flamelike locks of hair that are, once again, furrowed by broad, sharply chiseled grooves. As in the statue of Hadrian on Thasos (fig. 16), the crown of the head is left unfinished. Along the forehead, the central grooves are replaced by deep drill channels, as in the bun of the female head in Boston (fig. 14b). The very low relief of the beard in the Boston male portrait again recalls the statue from Thasos. In detail, however, it stands even closer to the Hadrian from Ostia (fig. 15a); the curls seem sharply chased into the surface and some of them have circular centers. In both heads, the upper lip has a sharp central point at the intersection of two curving arcs.

An extra dimension to the issues raised by the female portrait in Boston is conjured up by a roughed-out portrait of a lady with a crest of hair over her forehead found on Thasos (fig. 18).[69] Could such portraits have been exported from the island in the schematic state to be finished at their destination, just as sarcophagi and capitals were? Perhaps only the discovery of a schematic figure in a shipwreck or in a foreign marble depot could confirm the idea definitively, but an encouraging analogy is provided by the colossal statue of a Dacian formerly in the quarries at Dokimeion in Phrygia; as Waelkens has pointed out, the statue was certainly intended for the Forum of Trajan at Rome. Since it was fully shaped, lacking little more than the final polishing, it is clear that, under certain circumstances and from some quarries at least, statues were exported in a semifinished state. The question remains only if the Dacian, who was carved out of colored marble, was a special case because of his unusual stone.[70] In any event, a roughed-out relief, a bust of Asklepios, and a male torso have been

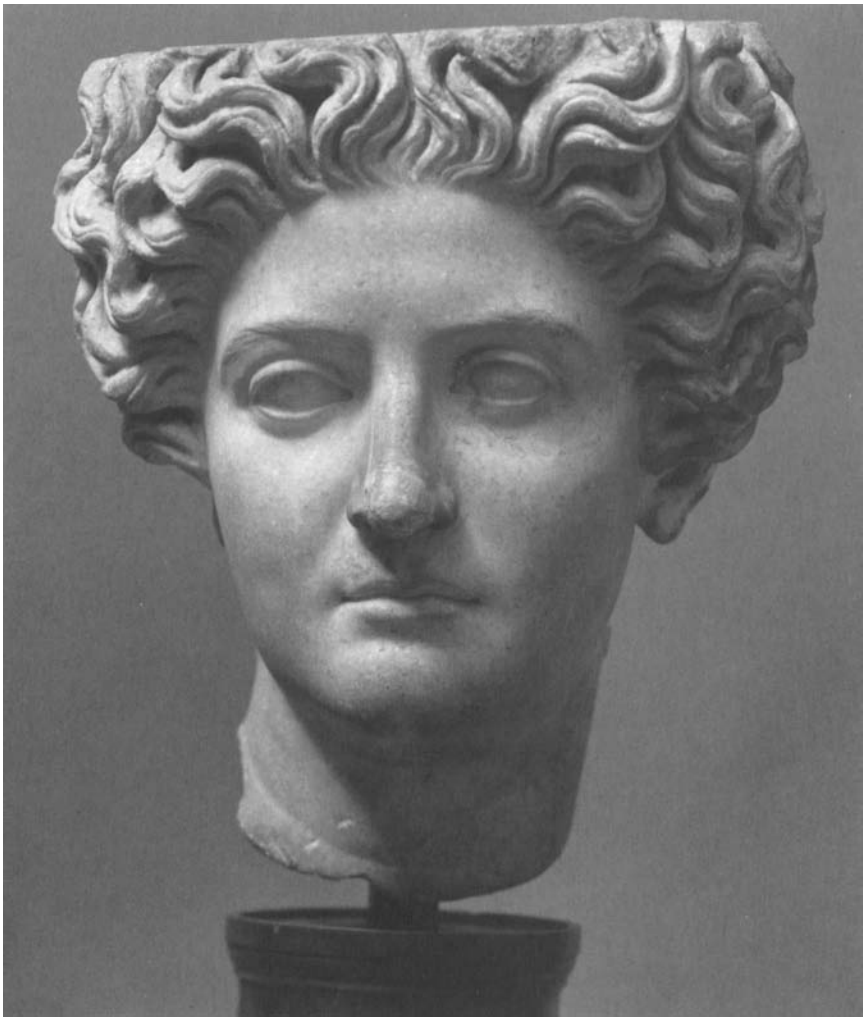


FIG. 14a

Female portrait with tiaralike hairstyle. Front. Boston, Museum of Fine Arts, Francis Bartlett Donation of 1900, 03.744. Photos: author.

FIG. 14b

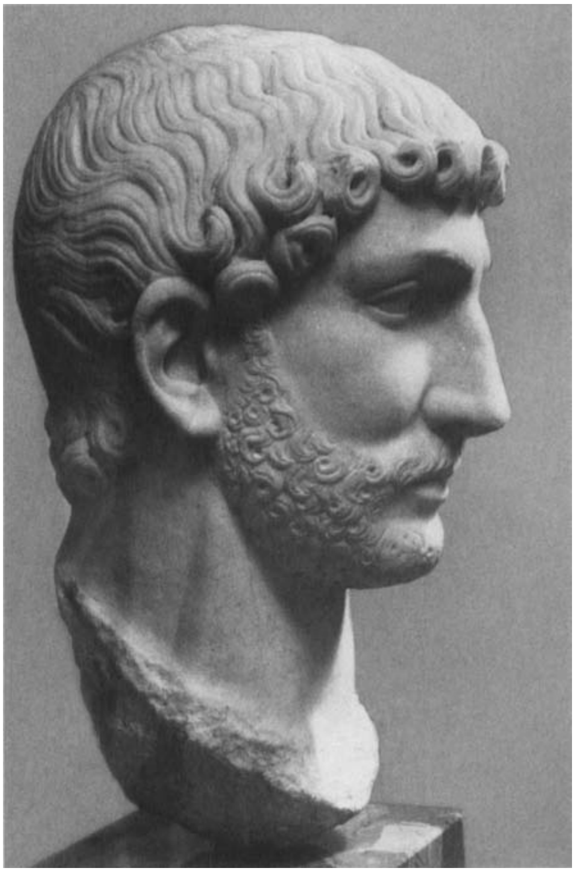
Right side of female portrait, figure 14a.

FIG. 14c

Back of female portrait, figure 14a.

discovered in the Saliari quarries;[71] they could well have been intended for export rather than for local consumption.

Two rather late ideal sculptures in the Museum of Fine Arts are not only made of Thasian marble but also connected to the late Classical and Hellenistic traditions of Thasos. While both have some claim to having been found in Rome, it seems possible that they were roughed out or even entirely carved by Thasians. It has been conjectured that a rather gloomy statuette of an Eleusinian goddess of Antonine or Severan date comes from Rome (fig. 19).[72] The same pose and drapery are presented by a somewhat under-life-size statue of Persephone in gray marble with a white marble face from the Gymnasium of Salamis in Cyprus.[73] The composition seems to be a variation on a popular type of Persephone of the fourth century B.C.;[74] the essential difference is that Persephone has been turned into the queen of the Underworld by giving her a veil and (in the case of the Boston statuette) a polos or *kalathos*.[75] A statuette that follows the more popular type without veil has been excavated in a deposit of votive gifts



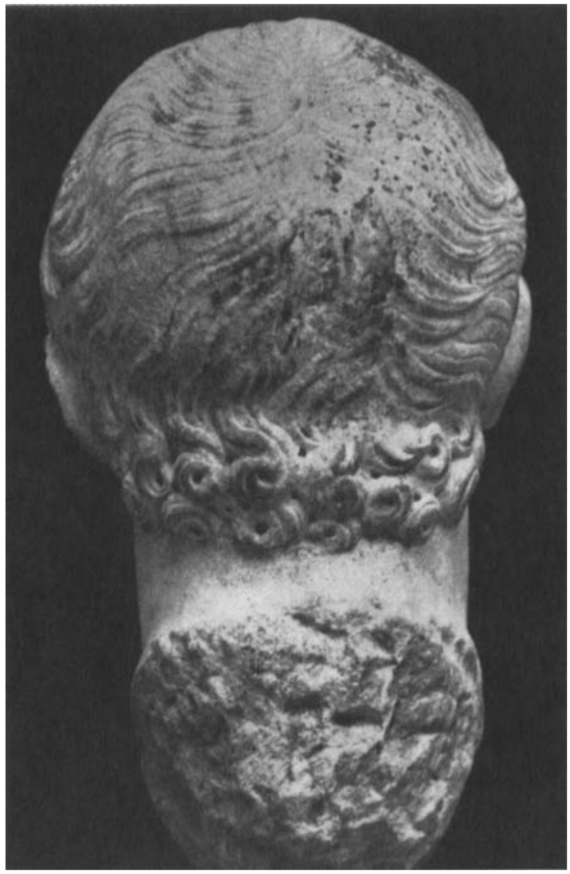


FIG. 15a

Portrait of Hadrian. Right side. Ostia, Museum 32. Photos: Istituto Centrale per il Catalogo e la Documentazione.

FIG. 15b

Back of portrait of Hadrian, figure 15a.

at the sanctuary of Evraiokastro on Thasos, where Zeus, Athena, and the Eleusinian goddesses were venerated (fig. 20).[76] It is quite possible that the veiled version of the figure was also known on Thasos. Since such small Eleusinian figures had entered the Thasian repertory, the Boston statuette could well have been carved by Thasians. While the statuette from Evraiokastro has the shallow, linear treatment common on the island – particularly in unfinished works of the Imperial period – the deep, doughy folds of the Boston figure can be seen in a late Hellenistic statuette of a nereid on a dolphin excavated on Thasos (fig. 21).[77] This kind of finishing might well have survived into middle Imperial times for more ambitious works. It is most likely, however, that the Boston Persephone was shipped from Thasos in a semifinished state. The comparably gloomy incomplete statuette of Hermes found on Thasos and now in the Getty Museum may well give an idea of how far work was carried in the quarries (fig. 22).[78] Excess material would have been removed, detail carved, and surfaces polished in Italy.

A colossal head of Dionysos in Boston is also in glittering, coarse-grained dolomitic marble (fig. 23).[79] The piece formerly had restorations that suggested a Roman provenance, but much about it would have been at the least congenial to a sculptor from Thasos. Typologically the head has something in common with the fine early Hellenistic Dionysos from an exedra of the Dionysion on Thasos (fig.

FIG. 16

Portrait statue of Hadrian. Thasos, Archaeological Museum 2346. Photo: Ecole française d'Athènes, neg. 31133.

FIG. 17

Antonine portrait. Boston, Museum of Fine Arts, gift of Paul E. Manheim 68.768. Photo: author.

FIG. 18

Unfinished female portrait with tiaralike hairstyle, from the rue de l'Acropole. Thasos, Archaeological Museum 3614. Photo: Ecole française d'Athènes, neg. L 4448 21A.

24).[80] The full, sharply outlined features of the Boston piece recall the Roman Imperial head of Alexander on Thasos (fig. 10), and the deeply drilled slots separating the strands of hair echo the "Romano-Thasian" female portrait in Boston (figs. 14a–c). Still, these techniques were generally available in Severan Rome; starting with the huge scale, the Dionysos displays many similarities to the colossal sculptures of the Baths of Caracalla;[81] if the sculptor of the Boston Dionysos did come from Thasos, he had been well assimilated into a Roman atelier.

Several sarcophagi of Hadrianic to Severan date are carved of coarse-grained dolomitic marble. All stem from Rome and are accomplished works fully in the local Italian style. They must have been carved in Italy from roughed-out tubs like those from the San Pietro wreck. The earliest and best-preserved is the magnificent late Hadrianic or early Antonine Orestes sarcophagus in Cleveland.[82] Its form is typically Roman – a long, low rectangular prism with a flat lid of the same Thasian material. Five fragments of sarcophagi in the Museum of Fine Arts are also of Thasian marble. One is a Hunt of the Kalydonian Boar.[83] Another is a fragment of a lid with the Trojan Horse.[84] A third is an agonized head of a barbarian.[85] Other fragments show a Muse with a theatrical mask[86] and a nude male, possibly Neptune with his trident.[87] Their suave use of drill work, which is fully compatible with Italian practice, makes it all but certain that these works were only roughed out in the quarries of the region around Vathy. An ash urn in Boston of around A.D. 200 with a Latin inscription could have been cut from Thasian marble exported to Italy as a block.[88]

A corner of a lid stemming from Rome, on loan to the Museum of Fine Arts, has a dry, linear style that is somewhat unusual in terms of the Roman tradition (fig. 25).[89] The technique can, on the other hand, be paralleled on Thasos, whether in modest Hellenistic works such as the torso from Evraiokastro (fig. 20) or in the

FIG. 19

Persephone. Boston, Museum of Fine Arts, gift of Paul E. Manheim 1970.242. Photo: Museum of Fine Arts.

FIG. 20

Torso from Evraiokastro. Thasos, Archaeological Museum 2103. Photo: Ecole française d'Athènes, neg. 32490.

drapery of Roman figures such as the unfinished statue of Hermes from Thasos, now in the Getty Museum (fig. 22).[90] It is likely that this dolomitic sarcophagus lid was carved by a Thasian immigrant in Italy, and it is at just this time – the first half of the third century – that the presence of Thasian architectural sculptors is attested in Italy.[91]

Roman portraiture provides evidence of the Thasian presence over wide areas of the Mediterranean. In some of these cases, it seems possible to identify an element of Thasian workmanship. A portrait in Thasian marble in the Cleveland Museum of Art was reportedly found in Egypt before World War II (fig. 26).[92] The authenticity of the piece, which has been questioned privately, seems defensible on the basis of its material and patination. The shaggy hair hanging down in front of the ears even recalls a Julio-Claudian portrait on Thasos (fig. 27).[93] The Cleveland piece may well be by an itinerant

FIG. 21

Goddess on a dolphin. Thasos, Archaeological Museum 19. Photo: Ecole française d'Athènes, neg. 31167.

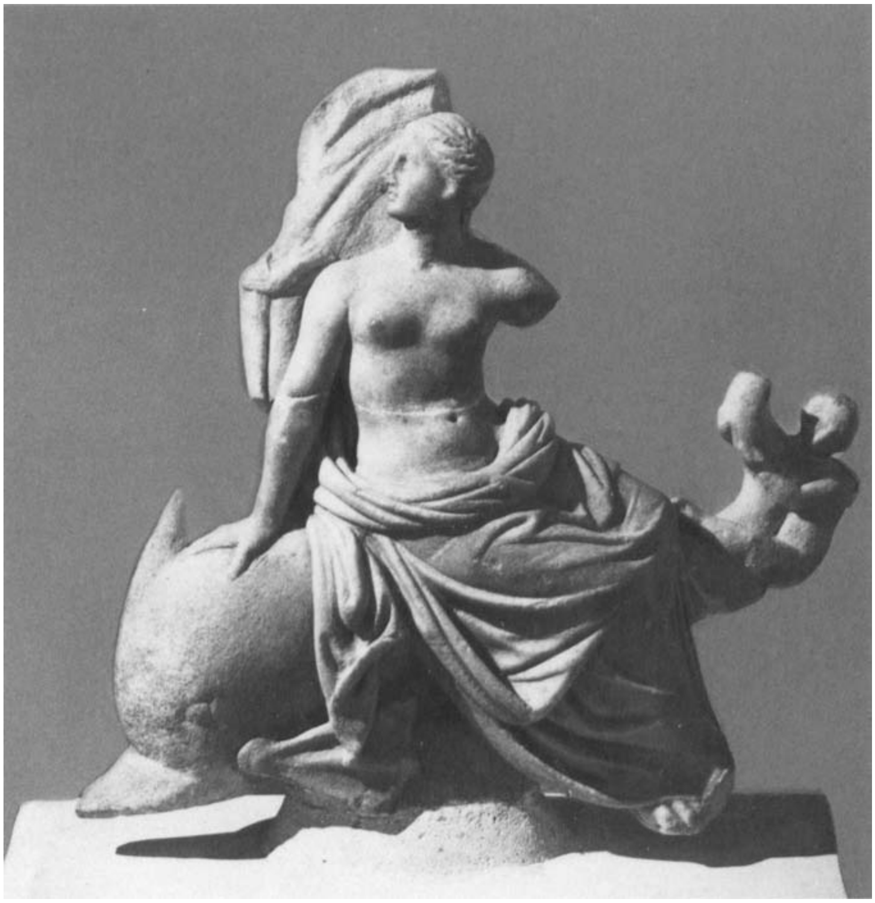


FIG. 22

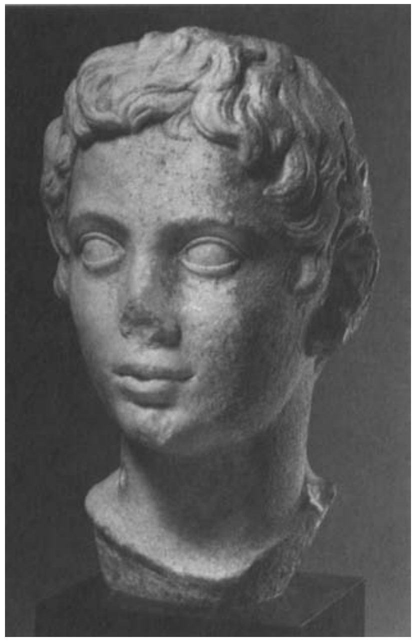
Roman statuette of Hermes found on Thasos. Malibu, J. Paul Getty Museum 71.AA.283.

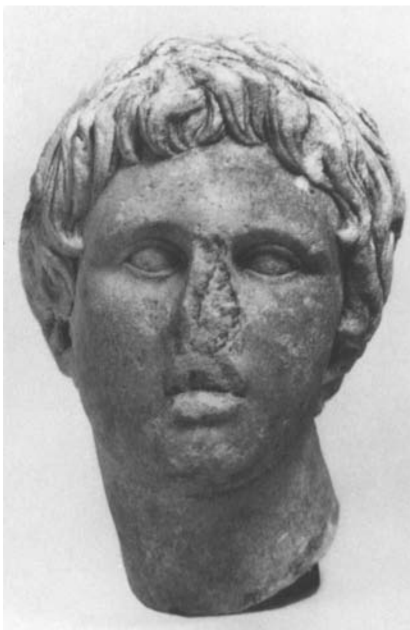
FIG. 23

Roman head of Dionysos. Boston, Museum of Fine Arts, gift of Edward Jackson Holmes 41.909. Photo: Museum of Fine Arts.

FIG. 24

Hellenistic head of Dionysos from the Dionysion. Thasos, Archaeological Museum 16. Photo: Ecole française d'Athènes, neg. 33861.





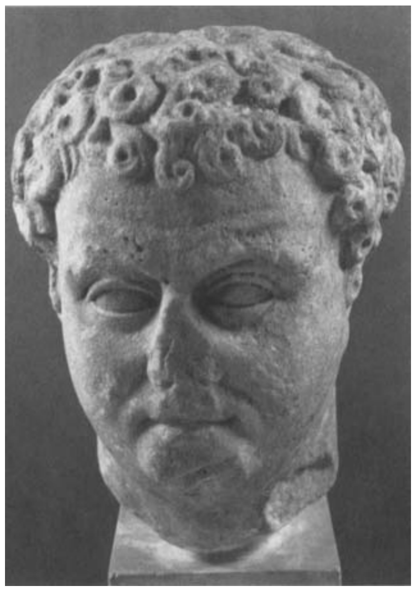


FIG. 25

Corner of a sarcophagus lid, on loan to the Museum of Fine Arts, Boston, T. L. 19.183. Photo: author.

FIG. 26

Portrait of a boy. The Cleveland Museum of Art, John L. Severance Fund 47.188. Photo: The Cleveland Museum of Art.

FIG. 27

Portrait of a boy from the rue de l'Acropole. Thasos, Archaeological Museum 3615. Photo: Ecole française d'Athènes, neg. R 1183,1.

FIG. 28

Portrait of a curly-haired man, perhaps Titus. Boston, Museum of Fine Arts, gift of Horace L. Mayer 63.2760. Photo: Museum of Fine Arts.

sculptor from the island.

A Flavian portrait in the Museum of Fine Arts, perhaps the emperor Titus, is also dolomitic marble (fig. 28).[94] The head, which is of unknown provenance, has already been attributed to the Aegean area. It may have been carved by a Thasian, but a close parallel on Thasos itself is hard to find.[95]

A dolomite roundel in the Museum of Fine Arts with two generalized portraits is said to have come from northern Greece (fig. 29).[96] The straightforward, simply chiseled work, which dates from the second quarter of the second century, is a provincial

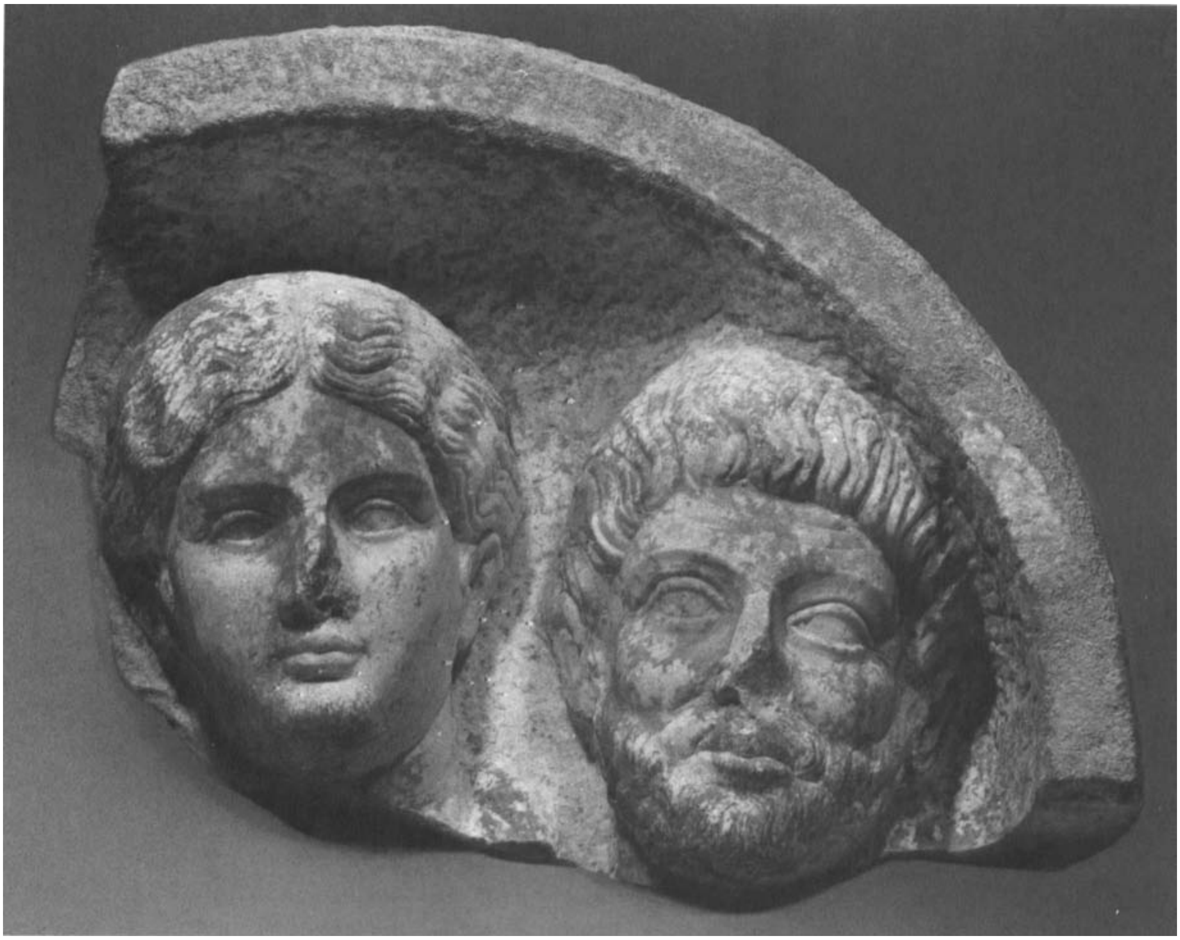


FIG. 29

Portrait roundel. Boston, Museum of Fine Arts, Classical Department exchange fund 1980.212. Photo: Museum of Fine Arts.

FIG. 30

Portrait roundel from Thasos, ex-Wix de Zsolna collection, ex-Sotheby's, London. Photo: Sotheby's.

production from the natural area of diffusion for Thasian marble and could well have been carved by a Thasian; a similar roundel, once in the Wix de Zsolna collection, was found on the island in the past (fig. 30),[97] and another example in Istanbul is thought to have the same origin.[98]

These simple tests, which hopefully can be confirmed by other forms of laboratory analysis, make it clear that marble from the Saliari region on Thasos played a small but significant role on the wider Mediterranean marketplace throughout antiquity. In some cases, identification of this material makes it possible to attribute a work of art to a regional school or confirm a provenance. Many questions, however, remain. While the marble must frequently have been shipped as raw material in the form of blocks or slabs – particularly in the case of exportation to Rome – could semifinished figures also have been exported? Did sculptors from Thasos migrate to Italy? If so, how much were they influenced by Italian traditions and to what degree were they assimilated into local workshops? Such problems will have to wait for solution, but the discovery of further works in Thasian marble will undoubtedly shed new light on the situation.

Museum of Fine Arts
BOSTON

Appendix 1 Possible Thasian Marble Objects in New England Analyzed with X-Ray Diffraction

by Richard Newman

The following table lists all the objects in the Boston area that were analyzed by X-ray diffraction for this article. The objects studied were chosen on the basis of the similarity of their visual appearance to samples of dolomitic Thasian marble. All were sampled on freshly broken or abraded surfaces to avoid possible interference from accretions or weathering layers. The samples were scrapings that included several grains of the rock. Because of the relatively coarse-grained nature of the rocks, it is possible that the small samples are not entirely representative of the overall average rock composition, but this would not adversely affect the value of the information for the present article. In nearly all cases, either dolomite or calcite was detected in the diffraction patterns; the major calcite line was faintly visible, indicating that a little calcite was present. We did not attempt to determine a "lower limit of detection" for small amounts of either calcite or dolomite in the presence of a large amount of the other.

Museum of Fine Arts, Boston

Three-sided relief, 08.205 (fig. 4)	dolomite
Polykleitan Hermes, 98.641	"
Head of youth, 03.746	"
Persephone ("Tyche-Fortuna"), 1970.242 (fig. 19)	"
Fragment of sarcophagus with Trojan Horse, 69.2	"
Cinerary urn, 1972.356	"
Female portrait, 03.744 (figs. 14a–c)	"
Antonine portrait, 68.768 (fig. 17)	"
Mask from a sarcophagus lid, TL 19.183 (fig. 25)	"
Sarcophagus with hunt, 1970.267	"
Portrait roundel, 1980.212 (fig. 29)	"
Female head from Assos, 84.64 (figs. 6a–b)	"
Polyphemos, 63.120 (fig. 12)	"
Portrait (Titus?), 63.2760 (fig. 28)	"
Dionysos, 41.909 (fig. 23)	"
Bearded head from a sarcophagus, 76.732	"
Sarcophagus fragment with a nude male, 76.749	"
Sarcophagus fragment with a mask, 76.729 (with a fair amount of calcite)	"
Kouros, 39.552	calcite
Archaic hand, 10.159	"
Herm-bust, 36.218	"
Herm-bust with a portrait, 99.342	"
Capitoline Aphrodite, 99.350	"
Small head of Zeus or Dionysos, 72.337	"
Antonine portrait bust, 24.419	"
Polykleitan head, 68.772	"
Osteotheke, 64.703, lid	"
Osteotheke, 64.703, box	"
Foot, 76.722	"
Akroterion from Assos, 84.25	"
Corner of an altar from Assos, 84.37	"
Table support, 28.893	"

Isabella Stewart Gardner Museum
(cat. no. = Vermeule et al. [note 57])

Torso, S27w64, cat. no. 26	dolomite
Head of Aphrodite, S5s21, cat. no. 37	calcite
Torso, S8e10, cat. no. 22	"
Small torso of Dionysos, S8e3, cat. no. 24	"
Priapos, S8e2, cat. no. 29	"
Sarcophagus, S8n4, cat. no. 58	"
Statuette, SG8e, cat. no. 17	"

Harvard University Art Museums

Head of athlete, 1922.171 (figs. 9a–b)	dolomite
Aphrodite, 1900.17	calcite
Narcissos, 1902.10	"
Meleager, 1926.48	"
Archaic relief head, 1969.175 (fig. 1) (previously tested by E. Farrell, L. Stodulski, and H. Donahue)	dolomite

Private collection on loan to the Yale University Art Gallery

Head of Pompey	dolomite

Appendix 2

Possible Thasian Marble Objects in the Cleveland Museum of Art Analyzed with X-Ray Diffraction

by Bruce Christman

Roman female head, 24.125 (fig. 13)	dolomite
Roman head of a boy, 47.188 (fig. 26)	"
Severe Style head of youth, 28.195 (figs. 5a–b)	"
Orestes sarcophagus, 28.856, body	"
Orestes sarcophagus, 28.856, lid	"

Notes

Comstock and Vermeule:
M. B. Comstock and C. C. Vermeule, *Sculpture in Stone: The Greek, Roman and Etruscan Collections of the Museum of Fine Arts, Boston* (Boston, 1976).

***Guide*:**
Ecole française d'Athènes, *Guide de Thasos* (Paris, 1967).

Vermeule and Comstock:
C. C. Vermeule, M. B. Comstock, et al., *Sculpture in Stone and Bronze: Additions to the Collections of Greek, Etruscan, and Roman Art, 1971–1988* (Boston, 1988).

The author would like to thank the directors, curators, and conservators whose cooperation made the tests outlined in the appendixes possible – in particular, Mary Comstock, Rollin van Ness Hadley, Arielle Kozloff, Barbara Mangum, David Mitten, and Cornelius Vermeule.

1 A very comprehensive presentation of colored marble and the sources on the marble trade appears in R. Gnoli, *Marmora romana* (Rome, 1971). On the marble depots along the Tiber and notable materials extracted from them, see ibid., pp. 22–23, 59, 151, 175, 187, 192, 196, fig. 4. On deposits at the mouth of the Tiber, see P. B. Leotardi, *Marmi di cava rinvenuti ad Ostia e considerazioni sul commercio dei marmi in età romana*. Vol. 10 of *Scavi di Ostia* (Rome, 1979).

2 R. Gnoli (note 1), passim. See also J. Ward-Perkins, *Enciclopedia dell'arte antica e orientale*, vol. 4 (Rome, 1961), s.v. "marmo," pp. 860–870; D. Monna, P. Pensabene, and J.-P. Sodini, "L'identificazione dei marmi: Necessità, metodi, limiti," in E. Dolci, ed., *Marmo restauro: Situazione e prospettive* (Carrara, 1983), pp. 34–52, pls. 1–14; idem, "L'identification des marbres: sa nécessité, ses méthodes, ses limites," in P. Pensabene, ed., *Marmi antichi: Problemi d'impiego, di restauro e d'identificazione*. Vol. 26 of *StMisc* (Rome, 1985), pp. 15–30; H. Dodge, "Decorative Stones for Architecture in the Roman Empire," *OJA* 7. 1 (1988), pp. 65–80.

3 G. Ferrari, *Il commercio dei sarcofagi asiatici* (Rome, 1966), pp. 89–95; W.-D. Heilmeyer, *Korinthische Normalkapitelle: Studien zur Geschichte der römischen Architekturdekoration. RömMitt*, Ergänzungsheft 16 (Heidelberg, 1970), pp. 17–24; P. Pensabene, *I capitelli*. Vol. 7 of *Scavi di Ostia* (Rome, 1973), esp. pp. 187–192.

4 For a comprehensive assessment, see Ferrari (note 3), pp. 17–23, 87–89; P. Pensabene, "Considerazioni sul trasporto di manufatti marmorei in età imperiale a Roma e in altri centri occidentali," *Dialoghi di archeologia* 6 (1972), pp. 317–362; J. Ward-Perkins, "Nikomedia and the Marble Trade," *BSR* 48, n.s. 35 (1980), pp. 23–69; Monna, Pensabene, and Sodini (note 2), pp. 45–47.

5 On this sequence of operations, see B. Ashmole, *Architect and Sculptor in Classical Greece* (New York, 1972), pp. 12–20. The unfinished kore in Taranto should also be considered in this perspective; she was exported in the roughed-out state to be finished by local artists at her destination; M. Santangelo, "Kore marmorea di Taranto," *BdA* 38 (1953), pp. 193–202; P. Pensabene, *Frammenti antichi del convento di S. Alessio*. Istituto di Studi Romani, Quaderni di storia dell'arte, vol. 20 (Rome, 1982), p. 57.

6 P. C. Bol, *Die Skulpturen des Schiffsfundes von Antikythera. AthMitt*, Beiheft 2 (Berlin, 1972), pp. 118–120, pls. 23–56; W. Fuchs, *Der Schiffsfund von Mahdia*. DAI Rome, Bilderhefte, vol. 2 (Tübingen, 1963), nos. 43–64, 66.

7 For a listing of Imperial shipwrecks, see Pensabene (note 4), pp. 331–333; one of the fullest reports is J. Ward-Perkins and P. Throckmorton, "The San Pietro Wreck," *Archaeology* 17 (1964), pp. 201–209. For the wreck at Punta Scifo near Crotone with a cargo of columns and blocks from Phrygia and blocks from Prokonnesos, see P. Pensabene, "A Cargo of Marble Shipwrecked at Punta Scifo near Crotone (Italy)," *JNautArch* 7.2 (1978), pp. 105–118; Dodge (note 2), pp. 72, 75.

8 On the stockpiling of marble at Rome up to the second quarter of the second century, see Ward-Perkins (note 4), pp. 25–26.

9 Pensabene (note 4), p. 331; M. Waelkens, "The Statues of the Dacian Prisoners in Trajan's Forum," *AJA* 89 (1985), pp. 644–645, 651–653, pls. 71–72.

10 N. Asgari, "Die Halbfabrikate kleinasiatischer Girlandensarkophage und ihre Herkunft," *AA*, 1977, pp. 348–349, fig. 52.

11 *Guide*, p. 176. On the edict, see Gnoli (note 1), pp. 12–13. For new fragments, see K. Erim and J. Reynolds, "The Copy of Diocletian's Edict on Maximum Prices from Aphrodisias in Caria," *JRS* 60 (1970), pp. 120–141, with a note on the marbles by M. H. Ballance, pp. 134–136.

12 J.-P. Sodini, A. Lambraki, and T. Koželj, "Les carrières de marbre a l'époque paléochrétienne," in Ecole française d'Athènes, *Aliki*, vol. 1. Vol. 9 of *Etudes thasiennes* (Paris, 1980), pp. 81–137.

13 T. Koželj, A. Muller, and J.-P. Sodini, "Carrières de marbre de la région de Saliari," *BCH* 104 (1980), pp. 962–963, fig. 70; T. Koželj, et al., "Sarcophages decouverts dans les carrières de Saliari (Thasos)," in Pensabene, ed. (note 2), pp. 75–77.

14 J. Herrmann and J.-P. Sodini, "Exportations de marbre thasien a l'époque paléochrétienne: Le cas des chapiteaux ioniques," *BCH* 101 (1977), pp. 471–510; J. Herrmann, *The Ionic Capital in Late Antique Rome* (Rome, 1988), pp. 79–93, pls. 61–67.

15 Herrmann and Sodini (note 14), pp. 494–498, 500–501, fig. 54; Herrmann (note 14), pp. 82, 88, 92, fig. 146.

16 On identifying marbles by eye and experience, see B. Ashmole, "Science and Common Sense," *BSA* 65 (1970), pp. 1–2.

17 K. Lehmann, *Samothrace: A Guide to the Excavations and the Museum* (New York, 1955), pp. 49, 58, 63, 81, 89, 90, fig. 43; P. M. Fraser, *Samothrace*, vol. 2, part 1. *The Inscriptions on Stone* (New York, 1960), passim; P. W. Lehmann, et al., *Samothrace*, vol. 5. *The Temenos* (Princeton, 1982), pp. 52, 89, 151, n. 9, 171, 174, 303, 399. See also *Guide*, p. 176.

18 Mr. Panagiotis Kazdamis, sculptor of the Thessaloniki Museum, has proposed that it comes from a quarry at Kozani in the Macedonian hinterland: H. P. Laubscher, *Der Reliefschmuck des Galeriusbogens in Thessaloniki*. Vol. 1 of DAI, *Archäologische Forschungen* (Berlin, 1975), pp. 20, 94, 145, n. 126. Simply on the grounds of practicality, however, it is more probable that the material was quarried on Thasos. From Aliki, it could have been shipped entirely by sea. From Kozani, on the other hand, the blocks would have followed a more difficult itinerary over land, river, and sea.

19 J. Ward-Perkins, "Workshops and Clients: The Dionysiac Sarcophagi in Baltimore," *RendPontAcc* 48 (1975–1976), pp. 205–206, 209–211, figs. 10–11, 13–15, 19, 20d, 23. The two pieces are the Triumph of Bacchus (23.31) and the Victory sarcophagus (23.36). They appear to be from the Saliari area on Thasos rather than from Aliki, as maintained by Ward-Perkins. For good illustrations of the Victory sarcophagus, see C. C. Vermeule, *Greek and Roman Sculpture in America* (Malibu, 1981), no. 201, color plate 21. Pensabene has recognized only one fragment of Thasian marble in a bath building at Ostia. Since 694 fragments were examined, this single Thasian piece argues either for the limited use of the material or for the caution of the observer: P. Pensabene, in A. Carandini, et al., *Le Terme del Nuotatore: Scavo degli ambienti III, VI, VII*. Vol. 21 of *StMisc* (Rome, 1973), pp. 637, 641.

20 A. Claridge, "Sulla lavorazione dei marmi bianchi nella scultura dell'età romana," in Pensabene, ed. (note 2), pp. 116–117, pl. 8.

21 N. Herz, S. E. Kane, and W. B. Hayes, "Isotopic Analysis of Sculpture from the Cyrene Demeter Sanctuary," in P. England and L. van Zelst, eds., *Application of Science in Examination of Works of Art* (Boston, 1985), pp. 142–149.

22 D. White, "Excavations in the Sanctuary of Demeter and Persephone at Cyrene 1973: Third Preliminary Report," *AJA* 79 (1975), p. 37, pl. 4, fig. 5 (inv. 73–1255); Herz, Kane, and Hayes (note 21), p. 147.

23 Compare F. Chamoux, *BCH* 73 (1949), fig. 27; B. Holtzmann and O. Picard, "Les abords ouest de l'agora," *BCH* 97 (1973), p. 539, fig. 6a.

24 W. Young and B. Ashmole, "The Boston Relief and the Ludovisi Throne," *BMFA* 66, no. 346 (1968), p. 141; D. Cordischi, D. Monna, and A. L. Segre, "ESR Analysis of Marble Samples from Mediterranean Quarries of Archaeological Interest," *Archaeometry* 25.1 (1983), pp. 68–76; see also N. Herz's survey of Thasos, "Classical Marble Quarries of Thásos," in G. A. Wagner, ed., *Antike Edel- und Buntmetallgewinnung auf Thasos* (forthcoming). The contrast between calcite at Aliki and dolomite at Vathy was also established by L. van Zelst, in Herrmann and Sodini (note 14), pp. 510–511.

25 A Thasian attribution for several pieces in Boston had already been suggested by Cornelius Vermeule and John Ward-Perkins. Pieces in Yale and in the J. Paul Getty Museum had been identified by Susan Matheson and Evelyn Harrison (transmitted by Marion True).

26 The utility of such a test has been noted by Monna, Pensabene, and Sodini (note 2), pp. 42–43.

27 Private communication via Richard Newman.

28 H. Hoffmann, *Collecting Greek Antiquities* (New York, 1971), p. 8, fig. 10; Vermeule (note 19), no. 10.

29 *Guide*, p. 117, fig. 56, no. 7.

30 B. Holtzmann, "Siphnos-Thasos-Paros," *BCH*, Suppl. 4 (1977), pp. 295ff.; E. Walter-Karydi, "Eine parische Peplophoros in Delphi," *JdI* 91 (1976), pp. 12f.

31 C. Kraay, *Archaic and Classical Greek Coins* (London, 1976), p. 149.

32 J. Paul Getty Museum 85.AA.40; J. Walsh, "Acquisitions/1985," *GettyMusJ* 14 (1986), no. 2, pp. 179–180; M. True, "A Kouros at the Getty Museum," *Burlington Magazine* 129 (January 1987), p. 10, citing an unpublished report by N. Herz.

33 C. C. Vermeule, "Catalogue of a Collection of Greek, Etruscan and Roman Antiquities" (unpublished manuscript, Cambridge, Mass., 1984), no. 6, pp. 13–14.

34 For the similar dolomitic character of the stone, see Young and Ashmole (note 24), pp. 141–145, 147; confirmed by Cordischi, Monna, and Segre (note 24), pp. 33–41; Monna, Pensabene, and Sodini (note 2), p. 42, n. 51; True (note 32), p. 10. Ludovisi Throne; D. Candilio, in A. Giuliano, ed., *Museo Nazionale Romano: Le sculture*, vol. 1, part 1 (Rome, 1979), no. 48. Boston relief; Comstock and Vermeule, no. 30; Vermeule and Comstock, p. 107.

35 B. S. Ridgway, *The Severe Style in Greek Sculpture* (Princeton, 1970), p. 50; M. Robertson, *A History of Greek Art* (Cambridge, 1975), pp. 203–209; Comstock and Vermeule, no. 30; for more recent bibl., see Vermeule and Comstock, p. 107.

36 E. Langlotz, *Studien zur nordostgriechischen Kunst* (Mainz am Rhein, 1975), pp. 123–124 (Ludovisi relief), 153 (Boston relief); R. Lullies and M. and A. Hirmer, *Griechische Plastik von den Anfängen bis zum Beginn der Römischen Kaiserzeit* (Munich, 1979), p. 76.

37 Stone analyzed by Bruce Christman, September 1987. On the sculpture, see Ridgway (note 35), pp. 59–60, figs. 88–91.

38 Ridgway (note 35), p. 60.

39 See Young and Ashmole (note 24), p. 128, fig. 4; Lullies and Hirmer (note 36), p. 76, pl. 114; G. Olbrich, "Ein grossgriechischer Akrolith im J. Paul Getty Museum," *GettyMusJ* 5 (1978), pp. 30–31, fig. 16.

40 True (note 32), p. 10, n. 57, citing an oral report of Bernard Holtzmann. Recent tests seem not to have confirmed this conjecture; see R. Alaimo and M. Carapezza, "De marmo della statua di Mozia: Caratteri geochimici e possibili aree di provenienza" in, N. Bonacasa and A. Buttitta, *La statua marmorea di Mozia e la scultura di stile severo in Sicilia* (Rome, 1988), pp. 29–37.

41 P. Devambez, "Sculptures thasiennes," *BCH* 66–67 (1942–1943), pp. 204ff., figs. 2, 3, pl. 10; A. Stewart, *Skopas of Paros* (Park Ridge, N.J., 1977), p. 115, pls. 47b–c; Lehmann, et al. (note 17), pp. 287, n. 67, 303.

42 A. Linfert, *Kunstzentren hellenistischer Zeit: Studien an weiblichen Gewandfiguren* (Wiesbaden, 1976), pp. 123–136, pls. 55–64.

43 Ibid., pp. 134–136.

44 Herz, Kane, and Hayes (note 21). Linfert's reconstruction of a Thasian influence at Palestrina, on the other hand, seems somewhat shaky and has not yet been supported by research on the materials.

45 Museum of Fine Arts 84.64; Comstock and Vermeule, no. 111.

46 R. Kabus-Jahn, *Die Grimanische Figurengruppe in Venedig. AntPl*, 11 (Berlin, 1972), p. 20, pl. 6; J. Boardman, *Greek Sculpture: The Classical Period* (London, 1985), p. 214, fig. 196.1. On the original location of the "Abbondanza," see the varying opinions collected by P. Karanastassis, "Untersuchungen zur kaiserzeitlichen Plastik in Griechenland II," *AthMitt* 102 (1987), p. 389, n. 310.

47 A comparably slender face can be found in the "Athena Velletri," a composition that Kabus-Jahn finds closely related to the "Abbondanza": Kabus-Jahn (note 46), p. 19, fig. 8; Boardman (note 46), fig. 202; Karanastassis (note 46), pp. 350–359, pls. 47–49, 54.1.

48 *Guide*, figs. 67, 68, nos. 25, 26. For another very similar Thasian fourth-century piece, see the head of Apollo bought on Thasos and now in the Wix de Zsolna collection, Vienna: H. Sitte, "Thasische Antiken," *ÖJh* 11 (1908), p. 156, fig. 48.

49 Referring also to previous doubts by the museum staff; K. Türr, *Fälschungen antiker Plastik seit 1800* (Berlin, 1984), K25, pp. 151–152. Previously considered Classical or early Hellenistic: G. H. Chase, *Fogg Art Museum Notes* 1 (1921), pp. 6–8, figs. 4–5; idem, *Greek and Roman Sculpture in American Collections* (Cambridge, Mass., 1924), p. 97, fig. 113; idem, *AJA* 26 (1922), pp. 204f., fig. 2; A. D. Fraser, *AJA* 29 (1925), pp. 70–75, fig. 1, pl. 2; A. W. Lawrence, *Classical Sculpture* (London, 1929), p. 242, pl. 789; *An Exhibition of Ancient Sculpture*, Fogg Art Museum, Cambridge, Mass., 1950, no. 37 (catalogue entry by G. M. A. Hanfmann).

50 C. C. Vermeule, *Harvard University Art Museums: Greek, Roman and Etruscan Stone Sculpture* (forthcoming), no. 20. Richard Newman has recently established (private communication) that the head lacks a calcitic layer at the surface, a phenomenon discussed in his article in this volume, and that the surviving incrustation – while thin – does not seem to be artificially applied.

51 Found in the destruction level over a temple foundation of the late fourth century B.C. – perhaps an Alexandreion: F. Blondé, A. Muller, and D. Mulliez, *BCH* 109 (1985), p. 879, fig. 6; idem, *RA*, 1987, pp. 32–34, 38, fig. 6.

52 The Harvard head is usually thought to reflect a Classical model.

53 M. Bieber, *The Sculpture of the Hellenistic Age* (New York, 1961), p. 161, figs. 682–685; L. de Lachenal, in Giuliano (note 34), no. 124.

54 Museum of Fine Arts 63.120; Comstock and Vermeule, no. 105; for recent bibl., see Vermeule and Comstock, p. 109.

55 On this accumulation, see Ward-Perkins (note 4), pp. 25–26.

56 Museum of Fine Arts 98.641; Comstock and Vermeule, no. 144. For recent bibl., see Vermeule and Comstock, p. 111. The head greatly resembles the head of the Diskophoros in Zurich, dated by Zanker to the time of Caligula: P. Zanker, *Klassizistische Statuen* (Mainz am Rhein, 1974), pl. 3.3, p. 4, n. 14. The Boston Hermes seems slightly more linear and could well be a little earlier than the Zurich piece, perhaps Tiberian. It is much less loose than Zanker's point of comparison, the head of Caligula in Adolphseck: H. von Heintze, *Die antiken Porträts in Schloss Fasanerie* (Mainz am Rhein, 1968), no. 21, pls. 34–35.

57 Gardner Museum S27W64; Cornelius Vermeule has already published the marble as Thasian; C. C. Vermeule, et al., *Sculpture in the Isabella Stewart Gardner Museum* (Boston, 1977), no. 26 (purchased in Rome).

58 Museum of Fine Arts 03.746; J. Fink, *RömMitt* 71 (1964), pp. 152–154, pl. 37.3; Comstock and Vermeule, no. 146. For the technique, compare the Antinous Farnese and the Kassel Paris: Zanker (note 56), p. 111, n. 122, pls. 5.4, 82.1.

59 From the Sangiorgi Galleries in Rome and previously in the Stroganoff collection in Rome. R. Howard, *Cleveland Museum of Art Bulletin* (February 1924), pp. 27–28; *Cleveland Museum of Art Handbook* (Cleveland, 1925), p. 62; ibid. (1928 ed.), p. 75; *Art News* (February 9, 1929), p. 22; M. Bieber, *Art in America* (July 1943), pp. 112–126, fig. 4; H. Fowler, *Festschrift für James Loeb* (Munich, 1930), pp. 63–65, pls. 4–5.

60 Compare R. Tölle-Kastenbein, *Frühklassische Peplosfiguren: Typen und Repliken. AntPl* 20 (Berlin, 1986), pls. 21–36. The braids that originally fell in front of the shoulders and down the back are probably a conflation with other types rather than a lingering Archaic feature of a mid-fifth-century model.

61 J. Raeder, *Die statuarische Ausstattung der Villa Hadriana bei Tivoli* (Frankfurt am Main and Bern, 1983), no. I 62, p. 220, pl. 10.

62 Museum of Fine Arts 03.744; Comstock and Vermeule, no. 349. For further bibl., see Vermeule and Comstock, p. 115.

63 K. Fittschen and P. Zanker, *Kaiserinnen- und Prinzessinnenbildnisse, Frauenporträts.* Vol. 3 of *Katalog der römischen Porträts in den Capitolinischen Museen und den anderen kommunalen Sammlungen der Stadt Rom* (Mainz am Rhein, 1983), no. 69, p. 54, n. 5.

64 For a somewhat similar cluster of curls, see a Hadrianic bust of a woman in the Schinz-Ruesch collection, Zurich; H. Jucker, *Das Bildnis im Blätterkelch: Geschichte und Bedeutung einer römischen Porträtform* (Olten, 1961), no. St 24, p. 82, pl. 31; C. Bossert-Radtke, in *Gesichter: Griechische und römische Bildnisse aus Schweizer Besitz*, Bernisches Historische Museum (3rd ed., Bern, 1983), no. 52 (catalogue ed. by H. Jucker and D. Willers).

65 R. Calza, *I Ritratti*. Part I, *Ritratti greci e romani fino al 160 circa d. C.* Vol. 5 of *Scavi di Ostia* (Rome, 1964), no. 117, pp. 73–74, pl. 68.

66 Fittschen and Zanker (note 63), p. 54, n. 5.

67 C. Rolley and F. Salviat, "Une statue d'Hadrien sur l'agora de Thasos," *BCH* 87 (1963), pp. 548–578, figs. 9–23; *Guide*, no. 45, p. 146, fig. 84.

68 Museum of Fine Arts 68.768; Comstock and Vermeule, no. 360.

69 A. Muller, *BCH* 104 (1980), p. 722, fig. 10. Numerous unfinished sculptures have been found in urban contexts on Thasos: see Sitte (note 48), pp. 148, 162, fig. 55; P. Devambez, "Sculptures thasiennes," *BCH* 66–67 (1942–1943), p. 225; G. Daux, *BCH* 75 (1951), pp. 166–168, fig. 74; J. Deshayes, *BCH* 76 (1952), p. 269, figs. 63–64.

70 M. Waelkens, "The Statues of the Dacian Prisoners in Trajan's Forum," *AJA* 89 (1985), pp. 644–645, 651–653, pls. 71–72.

71 Koželj, Muller, and Sodini (note 13), p. 963, fig. 71. The bust of Asklepios is mentioned in Herz (note 24). Prof. Herz informed me orally that the report is due to T. Koželj and that the piece has since been destroyed in quarrying operations. Interesting in this context is a Roman shipwreck with a cargo of unfinished marble products from the Prokonnesos, which included a pair of statues: M. Beykan, "The Marble Architectural Elements in Export-form from the Şile Shipwreck," in *Marble in Ancient Greece and Rome: Geology, Quarries, Commerce, Artifacts.* Abstracts of the Symposium, Lucca, May 9–13, 1988, p. 5 (Convenors N. Herz and M. Waelkens).

72 Museum of Fine Arts 1970.242; Comstock and Vermeule, no. 189.

73 V. Karageorghis and C. C. Vermeule, *Sculptures from Salamis*, vol. 1 (Nicosia, 1964), no. 15, pp. 24–25, pl. 22. For the recently discovered face, see V.

Karageorghis, *Annual Report of the Department of Antiquities for the Year 1983* (Nicosia, 1984), p. 51, no. 12, figs. 69, 72. An even closer parallel, which repeats the composition and attributes exactly, can be found in a bronze statuette in the Cabinet des Médailles: E. Babelon and J.-A. Blanchet, *Catalogue des bronzes antiques de la Bibliothèque Nationale* (Paris, 1895), pp. 37–38, no. 80; S. De Angeli, "Demeter/ Ceres," *LIMC*, vol. 4, p. 898, no. 75, pl. 602. Another exact parallel, in which the torch held in the right hand is well preserved, is provided by a marble statuette found in Samaria and identified from the context as Kore; see U. Avida in W. Dever, et al., *Treasures of the Holy Land*, exh. cat. (Metropolitan Museum of Art, 1986), no. 119. The figure is about a third larger than the Boston statuette.

74 The type was probably created under the influence of Euphranor: O. Palagia, *Euphranor* (Leiden, 1980), pp. 28–30, figs. 48–50, 54–55.

75 The attribute formerly held in the figure's right hand may well have been the torch of Persephone, as in the fourth-century composition. A problem, however, is created by the two pinholes in the upper right corner of the statue's plinth. The torch may have been replaced or repositioned in antiquity. Alternatively, the two holes may also provide a basis for reconstructing a rudder and interpreting the figure as Tyche: see Comstock and Vermeule, no. 189. For an exact parallel from Samaria with a well-preserved torch, see above, note 73.

76 G. Daux, *BCH* 87 (1963), p. 859, fig. 24, height 33 cm.

77 *Guide*, pp. 133, 136, no. 33, fig. 73.

78 Getty Museum 71.AA.283 (height 79.5 cm): Sitte (above, note 48), pp. 148, 162, fig. 55; C. C. Vermeule and N. Neuerburg, *Catalogue of the Ancient Art in the J. Paul Getty Museum: The Larger Statuary, Wall Paintings, and Mosaics* (Malibu, 1973), no. 45. According to Sitte, the statuette was found in an unspecified place in the chief city of the island with a number of other sculptures of varying dates.

79 Museum of Fine Arts 41.909; Comstock and Vermeule, no. 160: tentatively identified as Thasian and considered Praxitelean. It could also be a classicistic variation on Praxitelean types; cf. C. Gasparri, in *LIMC*, s.v. "Dionyos," no. 201, p. 445. For further bibl., see Vermeule and Comstock, p. 111.

80 *Guide*, pp. 130–133, fig. 69. In both works the languidly youthful Dionysos is without a headband. On a recent trip to Thasos, it appeared to the author that the Dionysos and several other early Hellenistic sculptures from the Dionysion (inv. nos. 652, 17, 1473 a, b) were carved in fine-grained, non-Thasian marble – probably Pentelic.

81 Comstock and Vermeule, no. 160, have noted the comparable scale. The similarity in workmanship has been brought out privately by Ariel Hamill Herrmann. See esp. the colossal head of Asklepios in the Museo Nazionale Romano: M. Marvin, "Freestanding Sculptures from the Baths of Caracalla," *AJA* 87 (1983), pp. 363–364, 381–382, pl. 49, fig. 12.

82 The Cleveland Museum of Art 28.856: R. Howard, "Orestes Sarcophagus and Greek Accessions," *Bulletin of the Cleveland Museum of Art* 15 (1928), pp. 85, 86, 90, 91; J. M. C. Toynbee, *The Hadrianic School* (Cambridge, 1934), pp. 183–184 (as in the Carducci collection, Rome); G. M. A. Hanfmann, *The Season Sarcophagus in Dumbarton Oaks*, vol. 2 (Cambridge, Mass., 1951), p. 170, no. 385; C. C. Vermeule, "Roman Sarcophagi in America: A Short Inventory," *Festschrift für Friedrich Matz* (Mainz, 1962), pp. 101–102; G. M. A. Hanfmann, *Roman Art* (Greenwich, Conn., 1964), p. 113, no. 119; C. C. Vermeule (note 19), no. 200, color plate 20.

83 Museum of Fine Arts 1970.267; Comstock and Vermeule, no. 241. For recent bibl., see Vermeule and Comstock, p. 112.

84 Museum of Fine Arts 69.2; Comstock and Vermeule, no. 242. For recent bibl., see Vermeule and Comstock, p. 112.

85 Museum of Fine Arts 76.732; Comstock and Vermeule, no. 267, tentatively identified as Thasian.

86 Museum of Fine Arts 76.729; Comstock and Vermeule, no. 253.

87 Museum of Fine Arts 76.749; Comstock and Vermeule, no. 257.

88 Museum of Fine Arts 1972.356; Comstock and Vermeule, no. 243. For recent bibl., see Vermeule and Comstock, pp. 112–113.

89 Museum of Fine Arts T.L. 19.183. Unpublished.

90 See note 78.

91 See note 15.

92 The Cleveland Museum of Art 47.188: S. Wunderlich, "A Marble Head of a Youth," *Bulletin of the Cleveland Museum of Art* (March 1948), pp. 37–39, illustrated; S. Lee, *Handbook of the Cleveland Museum of Art* (Cleveland, 1966), p. 24.

93 A. Muller, *BCH* 104 (1980), p. 722, fig. 9.

94 Museum of Fine Arts 63.2760; Comstock and Vermeule, no. 344. For recent bibl., see Vermeule and Comstock, p. 115.

95 For a good recent presentation of several portraits from Thasos and its region, see A.-K. Massner, "Corona civica, Priesterkranz oder Magistratinsigne? Bildnisse thasischer Theoroi?" *AthMitt* 103 (1988), pp. 239–250, pls. 31–34.

96 Museum of Fine Arts 1980.212: Vermeule and Comstock, pp. 54–55, no. 46.

97 Sitte (note 48), pp. 162–163, fig. 57; Sotheby's, London, Antiquities Sale cat., December 12, 1983, lot 551; ibid., May 31, 1990, lot 315.

98 G. Mendel, *Catalogue des sculptures grecques, romaines et byzantines*. Vol. 3 of *Musées Impériaux Ottomans* (Constantinople, 1914), no. 953.

Stable Isotope Analysis of Greek and Roman Marble: Provenance, Association, and Authenticity

Norman Herz

Classical archaeologists and art historians studying Greek and Roman marble artifacts have been plagued ever since the Renaissance with three important problems: (1) provenance of the marble, (2) correct association of broken fragments of a marble piece, and (3) authenticity of the artifacts. In the past, many archaeologists allowed themselves greater powers of discrimination than were justified and described marble pieces using place names as adjectives. The terms referred to the principal classical quarries and were based entirely on subjective aesthetic judgments. This practice led to many unresolvable controversies between art historians, archaeologists, and museum curators, and the literature is replete with contradictory descriptions of the same piece. Herz and Pritchett have published comparative lists of identical inscriptions showing that one epigrapher's "Pentelic" was another's "Hymettian."[1]

Lepsius was the first to describe systematically the major marble quarries of classical times and to point out their general physical characteristics.[2] According to his descriptions, Pentelic was a medium-grained, weakly foliated, sometimes micaceous marble; Hymettian was fine-grained and bluish; Parian medium- to coarse-grained, pure white, and translucent; and Naxian or merely "island" was a coarse-grained, white marble. Analytical methods for determining provenance were not available at that time, so Lepsius's descriptions became, and remained until quite recently, archaeological gospel.

The correct determination of marble provenance can serve many useful purposes. Since the periods of operation of many of the principal Greek and Roman quarries are well documented,[3] determining the provenance of an individual piece or collection can commonly also give the approximate date of fabrication, information on trading patterns, and insight into changing aesthetic tastes. In addition, knowledge of the source of the marble can also shed light on the authenticity of a piece.

Marble was first quarried on an apparently commercial basis in the Cyclades, on the island of Naxos in the seventh century B.C. By the sixth century production of marble had spread to

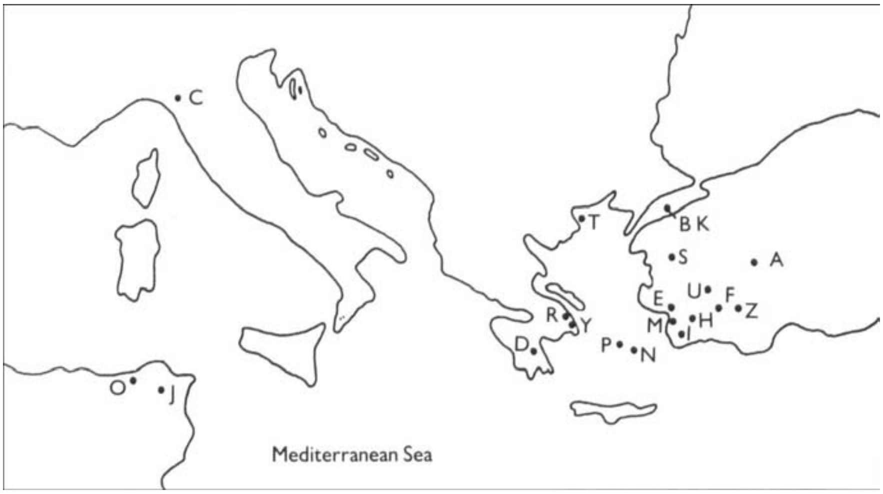


FIG. 1

Index map to classical Greek and Roman marble quarries. A: Afyon. B: Marmara. C: Carrara. D: Doliana. E: Ephesos. F: Aphrodisias. H: Herakleia. I: Iasos. J: Djebel Ichkeul. K: Iznik. M: Mylasa. N: Naxos. O: Chemtou. P: Paros. R: Pentelikon. S: Sardis. T: Thasos. U: Uşak. Y: Hymettos. Z: Denizli.

other islands of the Aegean, including Thasos and Paros (fig. 1).[4] So-called island marble, which was very coarse-grained, was traded extensively until the finer-grained, translucent *lychnites* marble of Paros came to be exploited in the early sixth century B.C. For construction of the great buildings of the Akropolis in Athens, in the late sixth and early fifth centuries B.C., marble quarries on Mount Pentelikon were opened up. The Parian *lychnites* marble was, however, still the preferred material for important statues and remained in use throughout Roman times and well into the Renaissance.[5]

Tastes started to change in Hellenistic times, continuing through the Roman era as colored marbles became more popular. Mount Hymettos, just east of Athens, produced a bluish, fine-grained marble from the late fifth century B.C. on. Other important marble sources include Doliana, used to construct the Tegea temple in the Peloponessos, and Thasos in the northern Aegean, which produced dolomitic marbles in the seventh century B.C. and the pure white calcitic marble of Aliki in Roman and Byzantine times. The Romans also opened up many quarries in Asia Minor, including one of their most popular – Prokonnesos in the Sea of Marmara – and Aphrodisias, Dokimeion, and other sites, which were exploited intermittently into Byzantine and modern times.

In addition to provenance determination, geochemical tests have proven useful in the assembly of broken fragments of a sculpture or an inscription. Stable isotopic ratio analysis (described below) has thus shown that three of six inscriptions in the Epigraphical Museum of Athens were incorrectly associated; that the Antonia Minor portrait of the Fogg Art Museum in Cambridge, Massachusetts, consisted of five unrelated fragments from Paros and Carrara;[6] and that the "Livia" head in the Ny Carlsberg Glyptotek in Copenhagen was composed of three unrelated pieces.

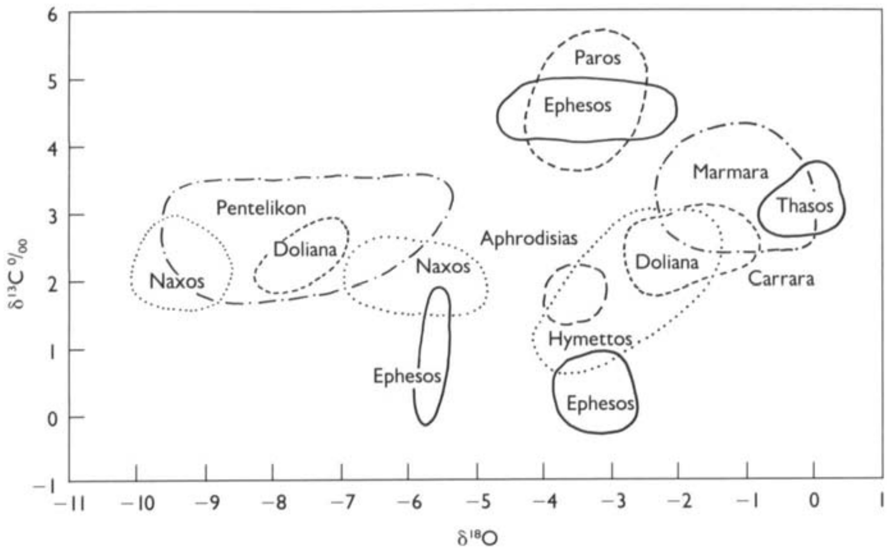


FIG. 2

$\delta^{13}C$ vs. $\delta^{18}O$ for the principal classical marble quarries. In parts per thousand, relative PDB (from Herz, "Isotopic Analysis of Marble," fig. 13.3).

ANALYTICAL TECHNIQUES

Many kinds of geological and geochemical analyses have been tried on marble in an attempt to resolve some of the problems described above. *Petrofabrics*,[7] which involves tedious microscopic study, has had some success in distinguishing some marbles. Unfortunately, the technique is not viable for most artifacts because of the lack of a data base and the need for a large amount of material for the analysis. A variety of *trace element analyses* have been tried, but unfortunately many trace elements vary by factors of over a hundred within the same quarry. Recently, multivariate statistical treatment of trace-element data has shown great promise for overcoming the inherent variability in the composition of the material.[8] Natural and artificial *thermoluminescence* (TL) analysis has been found useful for associating broken pieces of statuary, but differences found among TL curves within the same quarry are about as great as those between quarries.[9] *Electron-spin resonance spectroscopy* (ESR) of Mn^{2+} has been tried with some success.[10] Preliminary work suggests that some quarries can be distinguished, but detailed work in establishing inter- and intraquarry variation is now needed. Sr *isotopic ratios* are also promising: $^{87}Sr/^{86}Sr$ appears to vary significantly among the quarries tested,[11] but more detailed work is needed. Although none of these analytical techniques is as yet viable, the accumulation of data bases for ESR and trace elements should make them both acceptable in the near future.

At present, the most powerful technique for identifying quarry sources is isotopic ratio analysis of oxygen and carbon. The method was first suggested by the Craigs,[12] who used isotopic patterns plotted on a $\delta^{18}O - \delta^{13}C$ diagram (fig. 2). In a test of the method, they found that five of ten Greek and Roman archaeological marbles could be assigned a provenance. One great advantage of isotopic analysis is that it requires only very small amounts of marble, about 10 mg, which can readily be acquired without any visible damage to museum specimens. An extensive isotopic data base of the principal classical quarries has now been accumulated, and many marble inscriptions and statues have been related to their sources.[13] Isotopic analysis has also proven useful in associating broken fragments of marble pieces.

ISOTOPES AS SIGNATURES

Isotopic ratios of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ in natural materials vary as a result of geochemical fractionation. These variations in isotopes of oxygen and carbon as well as hydrogen, nitrogen, sulfur, strontium, and lead have helped resolve many geological and archaeological problems. On average, $^{16}O = 99.76\%$ and $^{18}O = 0.19\%$ of world oxygen; $^{12}C = 98.89\%$ and $^{13}C = 1.11\%$ of world carbon.[14] Stable isotopic ratios have proven especially useful in solving problems of provenance, palaeoenvironments, and palaeodiets in archaeology.

Isotopic fractionation of light elements is controlled by thermodynamic properties that are dependent on atomic weight and charge. Because isotopic franctionation is mass-dependent, the separation is greater for elements with a greater mass difference between isotopes. Thus, the greatest separation is found in hydrogen (mass 2) vs. deuterium (mass 3), a mass difference of 50%, in contrast to other light elements, whose mass differences may be closer to 10%. Thermodynamic properties of molecules that are mass and temperature dependent include energy, which decreases with decreasing temperature, and vibrational frequency, which varies inversely in proportion to mass. Thus the lighter isotopes have higher energy and their chemical bonds are more easily broken. The different reactivity of lighter vs. heavier isotopes is responsible for their separation during geochemical and biological processes. Because of varying geological histories, marbles in different quarries have each developed distinctive isotopic ratios (signatures) of oxygen and carbon.

For a signature to be viable, it must be uniform throughout an artifact, it should be relatively uniform in a quarry, and it should show only small variations within the limits of a mining district. Carbon and oxygen isotopes have been tested and found to meet these requirements.

Measurements of stable isotopic ratios are carried out with a mass spectrometer, an instrument that measures proportions in very small samples of different isotopic masses of several elements. In the newer, state-of-the-art machines, less than five mg of a sample are needed for an analysis. The precise measurement of the isotopic ratios $^{18}O/^{16}O$ and $^{13}C/^{12}C$ in marble is carried out after suitable chemical treatment has separated these elements in the form of CO_2 from the calcium carbonate. After the measurements by the mass spectrometer, the data are reduced by comparison to an accepted international standard and expressed as a deviation from a conventional standard, the Pee Dee belemnite, a carbonate fossil from South Carolina. This deviation, called δ, is expressed as $\delta^{13}C$ or $\delta^{18}O$, measured in parts per thousand (or per mill, ‰) and calculated as follows:

$$\delta\ (‰) = [R\ sample/R\ standard - 1]1000$$

where $R = {}^{13}C/{}^{12}C$ or ${}^{18}O/{}^{16}O$. Thus if marble has a $\delta^{18}O = +10‰$, the isotopic ratio of the oxygen is ten parts per thousand enriched in the heavy isotope ^{18}O compared to the standard. The isotopic variability data are usually expressed as a scatter plot of $\delta^{18}O$ and $\delta^{13}C$ values (see fig. 2).

Controls of the isotopic composition of oxygen and carbon in the carbonate of marble are principally through temperature, chemical composition, and isotopic ratios of water. The processes involved are:[15]

1. Mode of origin, either as a chemical precipitate, as a "hash" of organic shell fragments, or as a mixture of both, and composition of the cements
2. Isotopic composition of water associated with the carbonate minerals during their formation and later history
3. Temperature of the metamorphism that converted the limestone into marble and the extent of reactions and fractionation with adjacent rocks and with pore waters
4. Later weathering history

Through these processes marble from a given region formed at a particular time with its own geological history may develop unique isotopic characteristics.

Uniform isotopic composition can be attained over a wide area if (1) isotopic equilibrium was attained during the formation of the limestone and its later metamorphism to marble; (2) the marble unit is thick and relatively pure (i.e., free of other mineral phases); and (3) the metamorphic temperature gradient was not too steep.

Detailed tests have been carried out to determine the extent of isotopic uniformity in the Carrara district in Italy.[16] Variations appear to be less than 0.5‰ in $\delta^{13}C$ and less than 2‰

in $\delta^{18}O$ within a given outcrop or within most quarries. The two principal marble districts, the classical Roman Carrara and the Renaissance Seravezza, could be distinguished from each other, but individual quarries within each district could not be told apart.

Weathering may change the original isotopic composition of a marble sample. If different fragments of an artifact have different weathering histories – for example, if one piece has been buried in soil, another in a well, and a third in a wall – then each could have exchanged oxygen with waters that had different isotopic compositions and that were also quite different from those present at the time of formation of the marble. Since many artifacts can only be sampled near or on their surfaces, changes due to weathering must be assessed (Table 1). Weathering commonly causes little change in $\delta^{13}C$ but decreases $\delta^{18}O$ if exchanged with meteoric waters. A study of the Tate marble of Georgia showed that fifty years of weathering had caused a decrease of $\delta^{18}O$ of about 0.6‰.[17]

Table 1. $\delta^{13}C$ and $\delta^{18}O$ analysis of fresh and weathered marble (relative PDB) (from Herz, "Isotopic Analysis of Marble," fig. 13.3)

Sample Number*	$\delta^{13}C$	$\delta^{18}O$
1 Fresh	+1.17	−7.24
Weathered	+1.12	−7.93
2 Fresh	+1.37	−6.93
Weathered	+1.20	−7.45
3 Fresh	+2.57	−7.83
Weathered	+2.64	−8.16

*1 and 2 are from the Tate Quarry, Georgia; 3 is from a sarcophagus in the British Museum (from M. Coleman and S. Walker, "Stable Isotope Identification of Greek and Turkish Marbles," *Archaeometry* 21 [1979], pp. 107–112).

An isotopic data base of marble samples from the major ancient quarries of Greece, Turkey, Italy, and Tunisia now permits sourcing of artifacts.[18] The provenance of samples can be determined by comparison to the data base either by visual inspection of $\delta^{13}C$ vs. $\delta^{18}O$ plots, which are similar to our figure 2, or by a discriminant analysis computer program.[19]

RECENT APPLICATIONS OF ISOTOPIC METHODS

The first attempt to use isotopic ratios to prove an association of fragments was in a study of six disputed inscriptions in the Epigraphical Museum of the National Archaeological Museum in Athens.[20] It was found that for three inscriptions differences in $\delta^{13}C$ and $\delta^{18}O$ were greater than 0.4‰ in the broken pieces, suggesting that they could not have been part of the same original. Values in the other three inscriptions differed much less, showing that they could have been part of the same inscription or at least cut from the same quarry block.

The authenticity of the Antonia Minor portrait in the Fogg Art Museum at Harvard University had been debated for many years by art historians.[21] The head consisted of five fragments: isotopic analysis showed that three were Parian and two were Carrara marble.[22] Antonia apparently represented fragments of three different Roman statues – each Parian fragment was different isotopically – put together at some later time, with missing parts fitted with local Italian marble.

A well-known portrait, alleged to be Livia, in the Ny Carlsberg Glyptotek in Copenhagen (cat. no. 614), had also been challenged by art historians (fig. 3a). They cast doubt both on its authenticity and on its correct identification. It was found in the so-called tomb of the Licinii on the Via Salaria in Rome. Upon cleaning it became evident that the crown of the head was added at some later time, either in antiquity or during the Renaissance or later. If the skullcap did not belong to the rest of the portrait, then the identity of the piece would have to be changed.

Table 2. Isotopic analysis of the "Livia" head, Copenhagen, Ny Carlsberg Glyptotek, cat. no. 614 (relative PDB)

Piece	$\delta^{13}C$	$\delta^{18}O$	Composition	Source
Skullcap	+5.00	−2.99	dolomitic	Ephesos
Head	+5.38	−3.85	calcite	Paros
Nose	+2.09	−2.64	calcite	Carrara

Isotopic ratio analysis of the "Livia" portrait (Table 2) showed the head to be of Parian marble, which suggests that the head is authentic and made in Roman times. In both Greek and Roman antiquity all marble portraits of important persons were made of Parian marble, so "Livia" could very well represent an empress or the mother of an emperor. The skullcap was made of Ephesian marble, a popular Roman source, and could have come from any statue of the time. A later craftsman, wanting to make a complete portrait out of the

FIG. 3a

The previously labeled "Livia" marble portrait. Copenhagen, Ny Carlsberg Glyptotek, cat. no. 614. Photos: Ny Carlsberg Glyptotek.

FIG. 3b

The presently labeled "Agrippina" marble portrait, figure 3a.

Parian marble head, might have patched in the cap from a different Roman portrait. The nose is of Carrara marble, where quarries have operated from Roman times until the present,[23] so it could have been added at any time. Removing the skullcap from "Livia" (fig. 3a) revealed that iconographically the portrait is that of Agrippina (fig. 3b).

The J. Paul Getty Museum in Malibu recently obtained a larger-than-life statue of a Greek kouros that allegedly dates from 530 B.C. Since only about twelve complete kouroi are known worldwide, its significance was ranked with some of the Museum's most important acquisitions. Because some art historians voiced skepticism about the authenticity of the piece, isotopic analysis was carried out to see if provenance determination could help establish the piece as original. The results of this analysis showed:

$$\delta^{18}O = -2.37;\ \delta^{13}C = +2.88$$

Comparison of these numbers to the data base indicated the following quarries as possible sources: Denizli, Doliana, Marmara, Mylasa, and Thasos-Akropolis. X-ray diffraction revealed that the sample had a composition of 88% dolomite and 12% calcite. The only dolomitic marble sources in this group are Thasos-Akropolis, Marmara, and Denizli. Comparing next the trace-element composition of the kouros to the available trace-element data for Marmara and Denizli,[24] eliminated Denizli as a source. Comparing the dolomite content to that reported by Cordischi et al.[25] showed that Thasos marble had higher values, up to 100% dolomite, than Marmara with only about 57%. Discriminant function analysis[26] made it more than 90% probable that Thasos was the source of the marble for the kouros. Thus with the isotopic data as the first step, followed by ancillary analyses for trace elements and X ray and ESR for dolomite content, northeastern Thasos was revealed to be the most likely source for the marble. Historical evidence allows the

Akropolis source because (a) the oldest quarries of Thasos are known to be in that area, and (b) other large kouroi were produced on Thasos in the seventh and sixth centuries B.C.[27]

Isotopic analysis of patina can help determine the authenticity of an object. Although it is possible to make false classical marble statuary, it is more difficult to falsify a natural weathering patina. During the course of weathering, oxygen isotopes of the fresh marble will exchange with meteoric (atmosphere and groundwater) oxygen. Depending on the environment, the isotopic ratios of the weathered marble may equilibrate with those of the new environment. Oxygen composition of ocean water, relative the PDB standard, is $\delta^{18}O = -29.47‰$; meteoric water around the latitude of the Cyclades is about -32.4.[28] These strongly negative values indicate that any process of weathering in this area should decrease the ^{18}O on the surface compared to the fresh interior.

Alleged Early Bronze Age marble fragments analyzed in our labs were said to be from the same original although they displayed different weathering patterns. Isotopic analysis showed differences of 0.2‰ and less in carbon but 1.1–1.8‰ in oxygen. Knowing that carbon values change only slightly but that oxygen becomes more negative during weathering, the data was tested against the weathering patterns of the pieces. The most weathered pieces did indeed have the most negative oxygen values, which (a) allowed the fragments to be associated, and (b) suggested they were authentic.

Fresh marble from another alleged Bronze Age Cycladic sculpture showed $\delta^{18}O = -3.12$, $\delta^{13}C = +3.91$. The weathered surface was $\delta^{18}O = -2.87$, $\delta^{13}C = +3.91$. Again the question concerned the surface weathering: was it natural or artificial? Since the weathered marble in this case produced a higher $\delta^{18}O$ value than its fresh interior, the piece must be considered suspect.

Stable isotopic analysis of oxygen and carbon in marble produces distinct signatures for many classical Greek and Roman quarries. For quarries with overlapping values, ancillary analyses such as trace elements or dolomite content must be used to distinguish sources. Now that a large data base has been built up, isotopic analysis should be used routinely for tests of association of broken pieces of statuary or inscriptions, provenance of marble artifacts, and authenticity of weathering patina.

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Notes

I express my thanks to David B. Wenner for invaluable assistance in carrying out much of the project and for the support of the stable isotope laboratory at the University of Georgia. The work was supported by grants from the National Endowment for the Humanities, the National Geographic Society, and the Samuel H. Kress Foundation.

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Scientific Provenance Determination of Ancient White Marble Sculptures Using Petrographic, Chemical, and Isotopic Data

L. Moens, P. Roos, J. De Rudder, P. De Paepe, J. van Hende, and M. Waelkens

The implications for economic history of the identification of the marble sources of ancient art are evident. Even more important are its possibilities for the history of art. Since the nature of each stone to a large extent affects the possibilities of carving it, the identification of the provenance of the marble used in an ancient artifact may help us understand to what extent specific styles may have been imposed by the material that was used. Such an identification further helps us understand the logistics behind ancient art, exposing the network linking quarries with workshops or itinerant artists, and establishing the geographical range of their activities. Finally, a scientific identification of marble may also help us detect forgeries in the art trade or test the validity of earlier restorations.

In order to provide archaeologists with a reliable data base of "finger prints" characterizing stone from the major white marble quarries in use in antiquity, an interdisciplinary team has since 1984 undertaken an extensive sampling program in most ancient quarries of Italy, Greece, and Turkey (fig. 1).

The role of a given quarry as an important marble source, exporting its material over large distances, was a first and major criterion in selecting it for sampling. We included both quarries that exported already from the Archaic period onward (Naxos, Paros, Marmara/Prokonnesos) and quarries where this export was largely a phenomenon of the Roman period, even if some of those quarries may already have been active on a local, or even a regional scale, in the Classical or Hellenistic period (Pentelikon, Hymettos, Thasos, Afyon/Dokimeion, Aphrodisias, Carrara/Luni).

A second group of quarries was selected for its importance for "regional" markets: these quarries have many well-preserved artifacts whose provenance can or should be checked in order to distinguish local from imported material and to establish how smaller cities got their material for building or sculptural purposes (Doliana serving Mantinea and Tegea; Volos serving Pagasae and Demetrias; the quarries in the Uşak area serving Temenothyrai, Akmonia, and Sebaste; the quarries of the Denizli district serving the cities of the Lykos and the

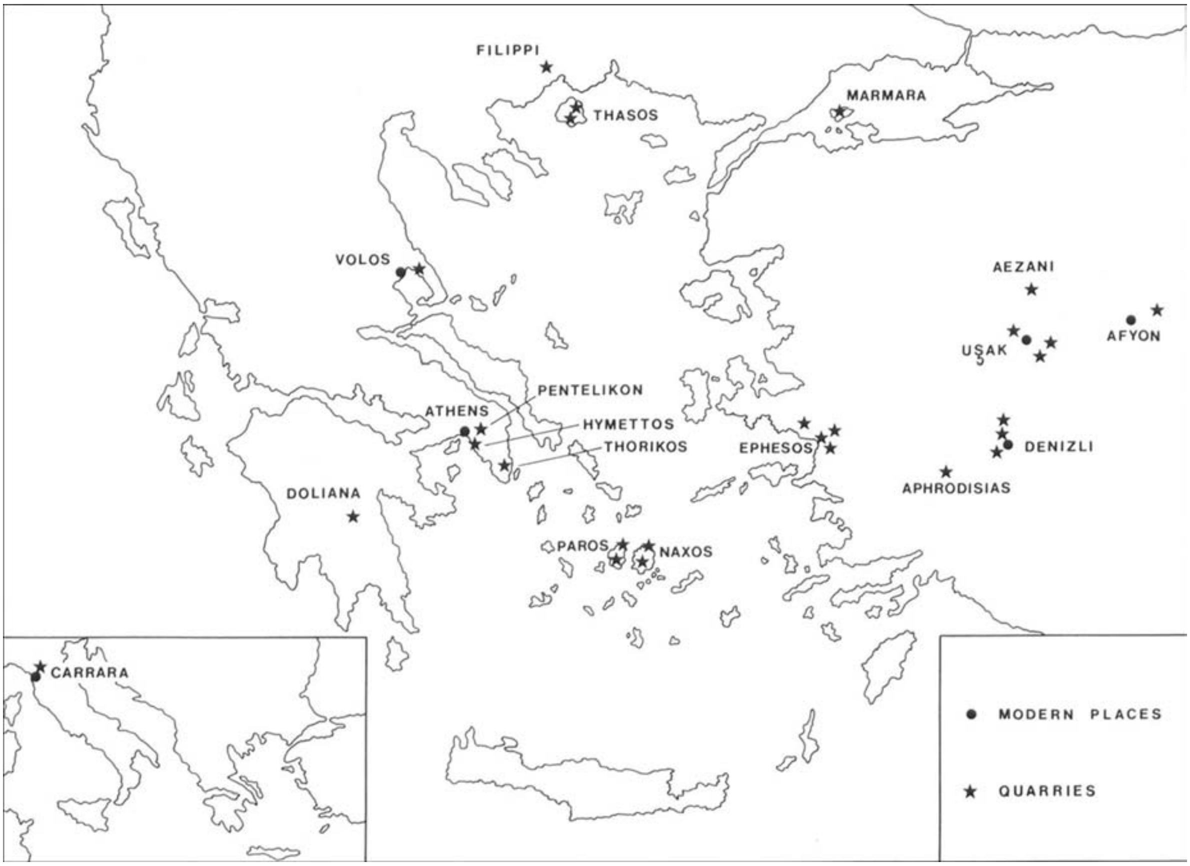


FIG. 1

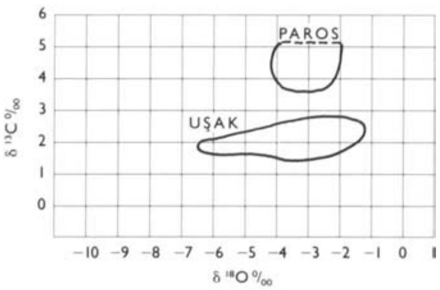
Ancient white marble districts included in the present project.

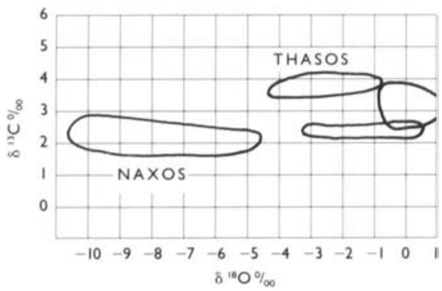
Upper Maeander valleys; the quarries near Ephesos serving that city and also the Kaystros Valley). For the same reason, other basically "local" quarries have been sampled because of the amount of well-preserved pieces of architecture and sculpture that may be supposed to have been extracted from them and whose provenance could thus be checked (Philippi, Aezani).

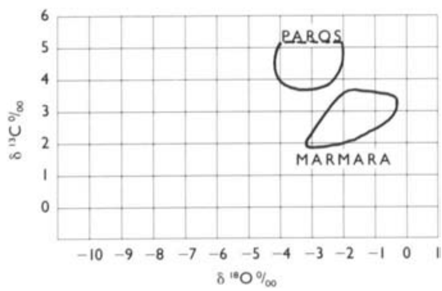
Since the quarries that have been sampled include all major exporting centers from the middle of the seventh century B.C. until the sixth century A.D., we can be reasonably confident that our sampling covers the possible provenances of most major artifacts in white marble produced during that period. At present about five hundred hand specimens from the above-mentioned quarry districts are available for analysis. In this paper results are presented for the districts of Carrara, Marmara, Afyon, Pentelikon, Paros, Naxos, Thasos, and Uşak.

Until the 1960s scholars tried to determine the origin of a stone from its appearance. Because visible differences between white marble from different regions can be very subtle, this approach is unreliable, especially since artifacts are often weathered. Therefore the natural sciences were called upon to establish objective criteria to characterize the marble from the major ancient quarry sites.

	CARRARA						
MARMARA	K, Mn, Co, Hf, MGS 0/51	MARMARA					
AFYON	Na, Sc, Cr, Mn, Fe, Sr, U, MGS 2/54	Cr, Mn, Co, Sr, U, MGS 0/51	AFYON				
UŞAK	Na, K, Cr, Mn, U, MGS 1/43	Co, U, MGS 4/40	Cr, Mn, Sr, U, MGS 1/43	UŞAK			
PENTELIKON	Al, Cr, Mn, Fe, Co, MGS 0/51	Mn, MGS 0/48	Na, Mn, Zn, Sr, La, Al, Sc, V 2/51	Mg, Al, Cr, Mn, Fe, Co, Zn, La, Th, U, MGS 0/40	PENTELIKON		
PAROS	Mg, MGS 0/49	Al, Mn 6/46	Mn, MGS 1/49		Mn, MGS 0/46	PAROS	
NAXOS	K, MGS 1/39	Al, Mn, MGS 0/36	Sc, Cr, MGS 1/39	Mn, MGS 2/28	Mn, Fe, MGS 0/36	Mn, Fe, MGS 2/34	NAXOS
THASOS	MGS 0/49	MGS 0/46	Mg, MGS 0/49	Zn, MGS 0/38	Mn, MGS 0/46	Mn, MGS 0/44	







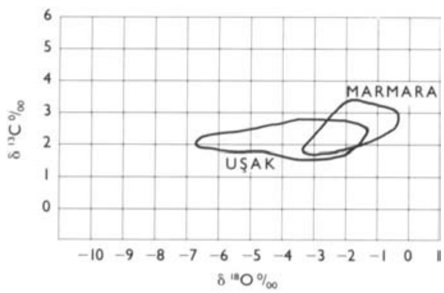


FIG. 2

Schematic representation of the two-by-two discrimination between the hitherto studied quarry districts. The selected arguments and the ratio of the misclassified samples to the total number of samples are indicated.

FIG. 3

Comparison of $\delta^{13}C/\delta^{18}O$-fields for the marble of Paros and Uşak (after Herz, *Archaeometry* [1987], fig. 2).

FIG. 4

Comparison of $\delta^{13}C/\delta^{18}O$-fields for the marble of Naxos and Thasos (after Herz, *Archaeometry* [1987], fig. 2).

FIG. 5

Comparison of $\delta^{13}C/\delta^{18}O$-fields for the marble of Paros and Marmara (after Herz, *Archaeometry* [1987], fig. 2).

FIG. 6

Comparison of $\delta^{13}C/\delta^{18}O$-fields for the marble of Uşak and Marmara (after Herz, *Archaeometry* [1987], fig. 2).

Several techniques were tested, and it soon turned out that any single technique failed to characterize each major quarry district with respect to all others; the subject was recently reviewed by Herz.[1] In the present project three different approaches are therefore used simultaneously: microscopy, chemical analysis, and isotopic analysis.

SAMPLING

It is no exaggeration to say that the reliability of the result of an analytical procedure is limited by the quality of the sampling. To establish a reliable material base in the present project, three prerequisites are of major importance.

First, the sample must be representative of the material that was extracted in antiquity. The latter is obviously not available in the quarries, and in most cases ancient quarries have been destroyed by more recent exploitations. Therefore it was decided not to limit the samples to ancient walls but to take them from all over the area where the ancient quarries are located. Thus one can be reasonably confident that the collected material is representative of that specific part of the marble outcrop.

Second, the geological context must also be taken into account. Rocks should be texturally and mineralogically homogeneous, not faulted, and free of disseminated ore deposits or mineralized veins.

Third, samples must be unweathered and unpolluted since only unaltered samples from both quarries and artifacts can be meaningfully compared.

Sampling was performed cooperatively by a team consisting of an archaeologist (M. W.), a geologist (P. D. P.), and an analytical chemist (L. M.). Samples of about one kg each were taken using a geological hammer. Occasionally weathered or superficially altered stones were collected in order to study the effect of long-standing exposure on the microscopic, chemical, and isotopic characteristics.

From the material available for the eight districts discussed in the present paper, 174 hand specimens were selected for analysis, excluding for instance grayish, dolomitic, or weathered stones.

From the hand specimens collected in the quarries, appropriate samples were taken for the different methods of analysis.

Using a diamond-tipped core drill and a diamond saw, at least two cylindrical samples (height = 20 mm, diameter = 15 mm), originating from more than one cm below the surface of the specimen, were removed for chemical analysis. The size of these samples was determined by the maximum amount of material expected to be obtainable from museum pieces.[2]

No more than 5–10 mg of marble is required for the precise determination of the relative abundance of ^{13}C and ^{18}O in the carbonate matrix. With a steel drill the necessary amount of powder is collected. For the production of thin sections, to be studied with a petrographic microscope, a slice is removed from the rock with the aid of a diamond saw.

When sampling an artifact, it is of major importance to cause as little damage as possible. The adopted sampling procedure for museum objects is analogous to the one applied to quarry samples in the laboratory, except that all samples of the former are prepared from a single core (diameter = 15 mm, height: approx. 60 mm).

ANALYTICAL TECHNIQUES

Thin-section microscopy. The main and accessory constituents of the rocks are identified with the aid of a polarizing microscope. The same equipment is used for studying the texture and for determining the maximum grain size (MGS) of the calcite grains. A staining technique is applied to the thin sections to distinguish calcite from dolomite. For this purpose alizarin red S is used.

Chemical analysis. For the determination of minor and trace elements, instrumental neutron activation analysis, atomic absorption spectrometry (using flame or electrothermal excitation), and colorimetry are used. In previous papers the analytical procedure has been described in more detail.[3] Suffice it here to say that it is possible to determine accurately and with good or acceptable precision the concentration of up to thirty elements in white marbles with a relatively high trace-element content.

Isotopic analysis. Using a vacuum extraction line, CO_2, prepared by dissolving the marble samples in 105% H_3PO_4, is purified and subsequently collected in a glass tube for off-line isotopic analysis. The relative abundance of the ^{13}C and ^{18}O isotopes is determined with a magnetic mass spectrometer (Finnigan MAT, Delta E). The $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios are measured relative to the ratios in a secondary standard. Results are reported as δ (per mill)-values versus PDB.

ANALYTICAL RESULTS

Thin-section microscopy. From the study of thin sections stained with alizarin red S, it was found that in most ancient quarries the marble is predominantly calcitic. Since moreover chemical analysis showed that dolomitic marble tends to display a trace-element pattern that can deviate strongly from calcitic marble of the same quarry area, samples containing more than ten percent of dolomite were excluded from this study. This implies for instance that none of the samples from the modern quarries in the area of Vathy and Saliari on the island of Thasos are considered here.

A detailed petrographic description of the studied samples is given elsewhere.[4] Summarizing, it can be concluded that, apart from dolomite, many other accessory minerals can be observed in white marble samples (e.g., plagioclase, muscovite, quartz, feldspar, epidote minerals, and opaque minerals). In the majority of the hitherto analyzed Italian, Greek, and Turkish marbles, however, there is little variation in the nature of the accessory minerals. Moreover their abundance rarely exceeds five percent of the volume of the rock, and the probability of observing them under the microscope therefore strongly depends on the random choice of the material used to make the thin section. Consequently, accessory minerals are of little use for characterizing white marbles.

Textural differences also occur. While the rocks from Carrara, Afyon, and Pentelikon display a well-developed homeoblastic texture, the texture of the marble from Marmara and Naxos is predominantly heteroblastic. Both textures can be found in the material from Paros and Thasos, whereas a mortar texture frequently appears in the marble from the Uşak province. A most useful criterion for interquarry discrimination turned out to be the maximum size of the calcite grains. For the hitherto studied sites, the range of the MGS-values is represented in Table 1. For many areas, ranges are mutually overlapping, but in some cases separated ranges allow the use of the MGS for direct discrimination (e.g., Thasos vs. all other districts except Paros and Naxos).

Table 1. Maximum grain size in the white marble of eight major quarry sites in Italy, Turkey, and Greece

Quarry district (number of samples)	Range Lowest value (mm)	Highest value (mm)	Median (mm)
Carrara (27)	0.6	1.3	0.8
Marmara (24)	2.2	3.6	2.9
Afyon (27)	0.8	1.8	1.2
Uşak (16)	1.2	3.4	1.95
Pentelikon (24)	0.9	1.5	1.2
Paros (22)	1.8	4.8	3.35
Naxos (12)	1.7	12.2	5.5
Thasos (22)	4.2	11.5	6.0

Chemical analysis. From the approximately thirty elements that can be determined in white marble, a selection of sixteen was made, omitting for instance elements yielding detection limits and using La as the only representative of the lanthanides. In Table 2 concentration ranges and medians are listed for the eight districts. Although medians for the different regions are often distinct, intradistrict ranges are wide, causing interdistrict overlaps for most elements. Occasionally separated ranges are observed, e.g., for K, Mn, and Hf in Carrara and Marmara.

Table 2. Concentration ranges and medians for eight quarry districts in Italy, Turkey, and Greece

Elements (units)	Carrara (27 samples) Range	Median	Marmara (24 samples) Range	Median	Afyon (27 samples) Range	Median	Uşak (16 samples) Range	Median
Na (ppm)	7.3 – 100.	20.4	2.07 – 43.8	7.1	3.03 – 63.	6.1	2.06 – 142.	11.9
Mg (%)	0.36 – 0.81	0.43	0.24 – 0.90	0.30	0.054 – 0.53	0.11	0.15 – 1.7	0.27
Al (ppm)	36.0 – 340.	167.	16.0 – 85.0	32.0	22.0 – 530.	70.	9.0 – 340.	82.5
K (ppm)	18.3 – 276.	95.	0.70 – 16.0	2.66	1.82 – 291.	18.2	0.0185 – 154.	4.36
Sc (ppb)	12.9 – 247.	71.	0.310 – 84.	15.1	7.4 – 208.	20.5	0.80 – 398.	24.9
V (ppb)	220. – 3650.	660.	90. – 2010.	480.	60. – 1140.	480.	200. – 3870.	410.
Cr (ppm)	0.215 – 2.87	1.97	0.230 – 3.97	1.85	0.0230 – 2.85	0.233	0.270 – 3.13	0.71
Mn (ppm)	11.1 – 73.	21.8	0.487 – 9.1	0.85	5.70 – 141.	25.5	1.52 – 51.0	14.6
Fe (ppm)	20.4 – 286.	98.	4.47 – 54.	16.8	15.9 – 500.	100.	13.0 – 450.	101.
Co (ppb)	17.3 – 124.	57.	1.34 – 49.	2.76	9.2 – 325.	37.3	3.86 – 278.	38.3
Zn (ppm)	0.76 – 5.22	1.83	0.260 – 6.00	2.09	0.356 – 5.74	0.91	0.299 – 14.2	0.67
Sr (ppm)	147. – 225.	170.	124. – 254.	165.	48.9 – 200.	95.	113. – 410.	210.
La (ppb)	231. – 1060.	430.	<1.9 – 1070.	28.5	36.4 – 860.	118.	32.5 – 2330.	94.
Hf (ppb)	5.3 – 30.	12.4	<1.3 – 5.0	2.8	1.7 – 44.	4.5	0.51 – 25.	4.2
Th (ppb)	9.5 – 101.	30.5	1.0 – 19.8	2.61	1.56 – 126.	10.3	<1.3 – 48.	9.9
U (ppb)	45.0 – 660.	127.	38.0 – 830.	212.	23.5 – 151.	53.	8.4 – 940.	102.

Elements (units)	Pentelikon (24 samples) Range	Median	Paros (22 samples) Range	Median	Naxos (12 samples) Range	Median	Thasos (22 samples) Range	Median
Na (ppm)	10.9 – 164.	30.9	1.53 – 32.1	8.35	2.44 – 31.8	5.3	5.2 – 68.	23.2
Mg (%)	0.25 – 0.87	0.35	0.14 – 0.47	0.26	0.13 – 0.63	0.28	0.27 – 0.43	0.35
Al (ppm)	20.0 – 1070.	340.	16.0 – 810.	90.	58.0 – 468.	159.	16.0 – 409.	121.
K (ppm)	6.21 – 411.	34.9	0.93 – 470.	22.0	0.47 – 247.	5.44	1.94 – 382.	28.8
Sc (ppb)	14.0 – 232.	48.1	2.49 – 217.	61.2	23.0 – 179.	30.2	4.29 – 607.	142.
V (ppb)	150. – 1050.	420.	280. – 3080.	620.	44. – 9800.	710.	150. – 2280.	570.
Cr (ppm)	0.158 – 1.04	0.52	0.253 – 5.78	0.93	0.259 – 4.49	0.96	0.292 – 1.31	0.545
Mn (ppm)	37.3 – 294.	68.	1.68 – 39.0	6.0	3.13 – 112.	24.8	2.19 – 84.	23.5
Fe (ppm)	89. – 880.	240.	4.77 – 301.	41.6	23.9 – 162.	49.5	8.1 – 367.	47.9
Co (ppb)	14.6 – 355.	48.1	3.38 – 93.	24.4	8.2 – 122.	25.5	5.9 – 121.	27.8
Zn (ppm)	0.81 – 9.4	3.73	0.301 – 2.96	1.91	0.66 – 12.4	1.84	0.334 – 43.4	7.4
Sr (ppm)	105. – 248.	181.	56.5 – 293.	160.	85. – 298.	151.	107. – 179.	141.
La (ppb)	215. – 1960.	720.	60.5 – 2850.	690.	107. – 1150.	420.	54.0 – 3680.	800.
Hf (ppb)	<1.5 – 58.	3.5	<0.4 – 32.	2.5	2.0 – 21.	7.1	<1.75 – 47.	4.2
Th (ppb)	4.9 – 261.	21.7	1.10 – 128.	19.6	8.2 – 69.	20.2	2.02 – 122.	20.1
U (ppb)	9.6 – 109.	42.8	23.3 – 1290.	65.	29.9 – 4720.	75.	12.8 – 347.	85.

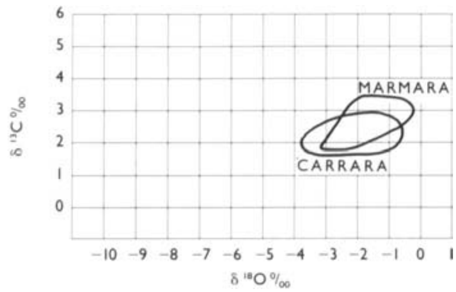


FIG. 7

Comparison of $\delta^{13}C/\delta^{18}O$-fields for the marble of Marmara and Carrara (after Herz, *Archaeometry* [1987], fig. 2).

It was found that for virtually all elements the frequency distribution of the concentrations is not normal and that a log-normal distribution is a far better approximation.[5] Though it is essential to know the distribution shape when performing statistical analysis on the data, the matter was insufficiently studied in the past.

Isotopic analysis. Only recently were the first quarry samples subjected to isotopic analysis. For the time being, literature data[6] are used as a reference when analyzing samples from artifacts.

INTERQUARRY DISCRIMINATION

Based on chemical and granulometric data. In general, direct discrimination between quarries based on a single chemical or petrographic test is impossible. Multivariate methods are therefore needed to reveal the discriminating information expected to be present in the data set. In this work, cluster analysis was performed. A pragmatic choice was made for an hierarchical clustering method using the Euclidean distance as a dissimilarity measure and the Wards error sum clustering strategy. A logarithmic transformation was applied to the elemental concentrations according to the adopted log-normal empiricism. Running the program for different sets of attributes allowed the selection of the discriminating ones. As no one set of attributes was found to separate all districts in a single dendrogram, a set of discriminants was selected for each pair of districts. With this set, the ratio of the interdistrict dissimilarity to the intradistrict dissimilarities is maximal.

The result of this selection is schematically shown in figure 2, where the total number of samples involved in the comparison and the number of misclassified samples is indicated as well. In fifteen out of twenty-eight two-by-two comparisons the samples of both sites are correctly separated. In nine other cases the discrimination is incomplete, but only one or two of the samples are misclassified. For four pairs the chemical and textural similarity of the marble is so strong that a satisfactory separation is impossible (ten percent or more of the samples are misclassified).

It can be concluded that chemical and granulometric data contribute substantially to interquarry discrimination.

Complementary information from isotopic analysis. The isotopic data library established by Norman Herz is

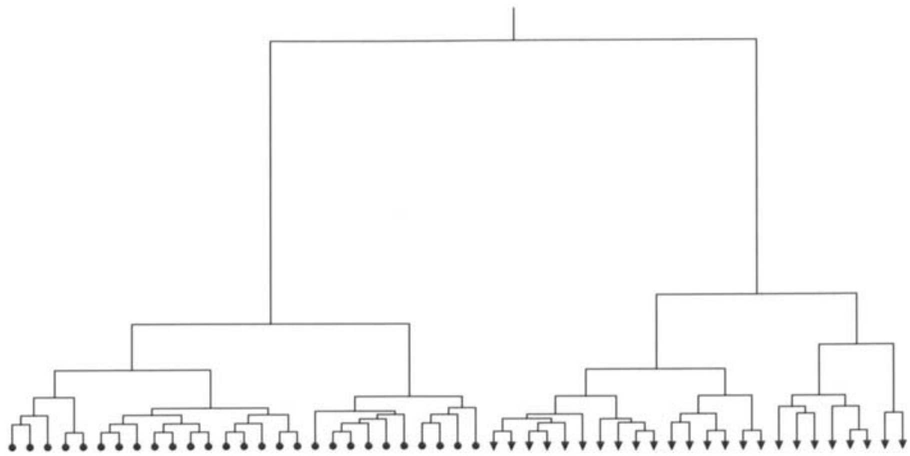


FIG. 8

Classification dendrogram for fifty-one samples from Marmara (∇) and Carrara (O); (relative dissimilarity scale); attributes: K, Mn, Co, Hf, MGS.

probably one of the most complete available at present. From the diagrams shown in a recent paper on this data base,[7] it appears that isotopic data strikingly complement petrographic and chemical information. In figures 3–6, isotope fields are shown for each of the quarry-pairs that could not be separated using granulometry and chemical analysis. It can be seen that for three pairs the $\delta^{13}C/\delta^{18}O$ fields show no overlap at all (figs. 3–5). On the other hand, chemical and granulometric data allow distinction between several quarries for which isotopic analysis shows overlapping fields. This is illustrated in figures 7 and 8 for the districts of Carrara and Marmara. Cluster analysis using the MGS and K, Mn, Co, and Hf contents yields a dendrogram representing two clearly separate clusters (fig. 8).

In the near future we will complete our isotopic analyses and apply multivariate methods to the combined information of all three analytical techniques applied in the present project. In view of the above, we are optimistic about the ability of this approach to characterize most major quarry regions with respect to the others. It is even conceivable that districts such as Uşak and Marmara, which presently can be separated by neither of the individual approaches (figs. 2, 6), will be distinguished when all three methods are applied to the same samples.

ARCHAEOLOGICAL APPLICATIONS

Provenance determination of artifacts. For provenancing artifacts, the two-by-two discrimination method, based on granulometric and chemical data, can be applied as well. Using the parameters found to separate a given pair of quarry sites (fig. 2), cluster analysis is performed on the data of the quarry samples, complemented with the data for the artifact. Repeating this procedure for each pair of sites makes it possible to determine the most probable origin of the artifact by successive elimination. As a complement, isotopic data for the artifact at present are compared to the $\delta^{13}C/\delta^{18}O$ fields published by Herz.[8]

To demonstrate this strategy, the provenance of two reliefs from a private collection is briefly described here; a full report

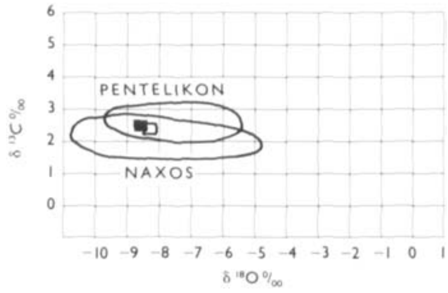


FIG. 9

Isotopic composition of two reliefs (Three Graces: □; fragment of a grave relief: ■), compared to the $\delta^{13}C/\delta^{18}O$-fields for the marble of the quarries of Naxos and Mount Pentelikon (after Herz, *Archaeometry* [1987], fig. 2).

is given elsewhere.[9] The sculptures were purchased from an antique dealer in Greece, who unfortunately could give no information on their origin. Both sculptures were shown to the public during the exhibition "Marmer in Hellas" (Brussels, December 18, 1987, to April 13, 1988), organized by the Gemeentekrediet van België in cooperation with the Seminarie voor Griekse Archeologie (Director: Professor Dr. H. Mussche) of the Rijksuniversiteit Gent. The sculptures are numbers 142 and 144 in the catalogue of this exhibition.[10] The reliefs were subjected to an art historical investigation,[11] the results of which are briefly summarized in Table 3. A sample was removed from the bottom side of the votive relief representing the Three Graces. For the fragment of the grave relief, a sample was removed from a fracture.

Table 3. Art historical description of two reliefs studied in this work

Relief	Dated	Height (cm)	Width (cm)
Three Graces	Early fourth century B.C., after prototype of second half of fifth century	14	20
Woman, fragment of grave relief	First century A.D., drawing on a type of the late fourth century B.C.	24	16

Analytical results for these artifacts were compared to the data for the eight major quarries considered in this paper. Their isotopic composition suggests that both sculptures were carved from marble from either Naxos or Mount Pentelikon (fig. 9). Chemical and granulometric characteristics independently indicate Pentelikon as the more likely provenance of the marble. It is not feasible to show all dendrograms this conclusion is based upon; suffice it to include here the dendrograms separating the material from Naxos and Pentelikon, which clearly demonstrate that both artifacts are made of Pentelic marble (figs. 10, 11). These dendrograms are particularly interesting because they complement the ambiguous result from isotopic analysis that was shown in figure 9.

Note that the isotopic signatures of both artifacts in principle could refer to the quarries of Iznik or Sardis as well, though archaeological considerations do not point in this direction.

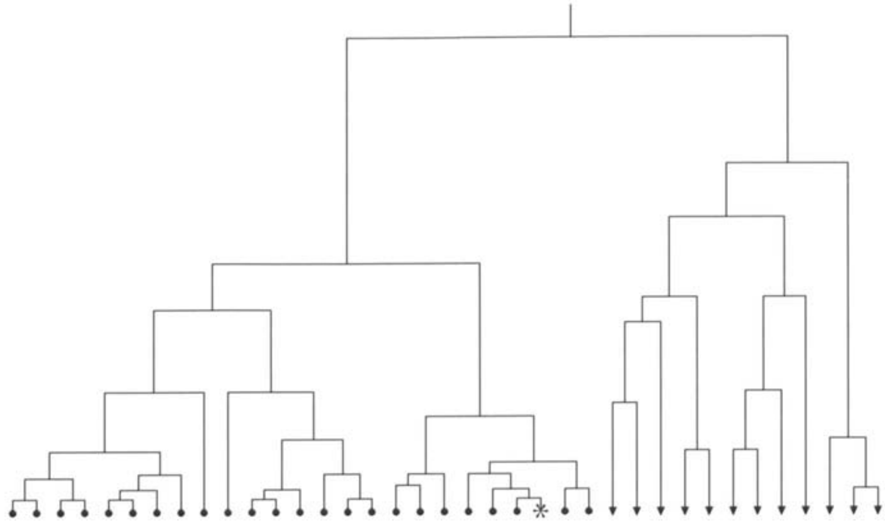


FIG. 10

Classification dendrogram for thirty-six samples from Naxos (▽) and Pentelikon (O) and for the sample from the votive relief of the Three Graces (*); (relative dissimilarity scale); attributes: Mn, Fe, MGS.

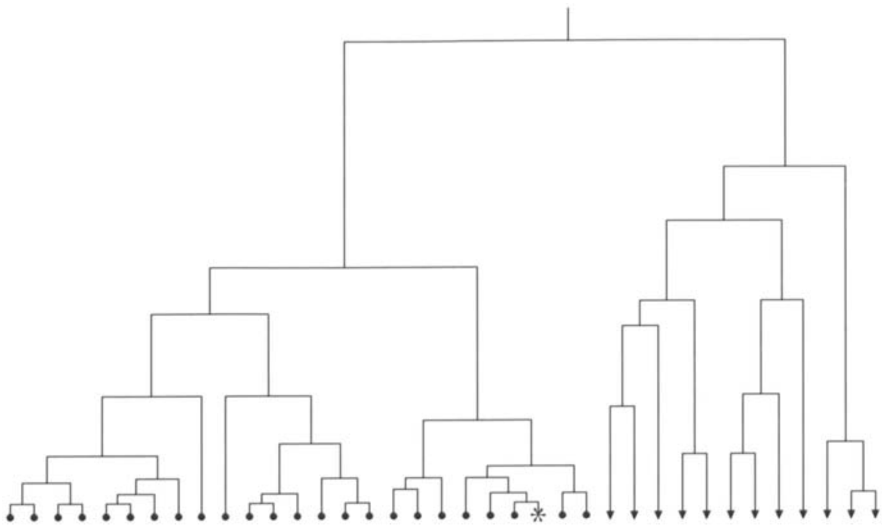


FIG. 11

Classification dendrogram for thirty-six samples from Naxos (▽) and Pentelikon (O) and for the sample from the fragment of a grave relief (*); (relative dissimilarity scale); attributes: Mn, Fe, MGS.

However, as no other techniques were applied to the material of these districts, it is not possible to exclude this hypothesis completely.

Authentication. Obviously the two-by-two discrimination method can be used to reveal falsifications whenever the provenance of the marble used to make the forgery is incompatible with its art-historical characteristics. To demonstrate this principle, a modern sculptor was asked to make a copy of a Cycladic idol from Paros using commercially available marble of his choice.[12] Chemical, granulometric, and isotopic data showed that the idol was made of Pentelic marble, proving the falsification.

CONCLUSION

During the past decades, several scientific methods have been used to determine the provenance of ancient marble. It has been known for many years that no single technique allows distinction between the marble from all major quarries and that the combined information of different complementary methods would be needed to achieve this. At present we are confident that combining the data from petrographic, chemical, and isotopic (i.e., stable isotopes of C and O) analyses will bring us close to the premised goal.

Though the sample size required for this multimethod approach is considerable, it has turned out not to be prohibitive. Indeed, a limited number of artifacts have already been studied, and requests for large-scale investigations on museum pieces have been received.

In the near future, other scientific methods will be applied to our material base (e.g., Sr-isotopes and cathodoluminescence) in order to confirm our conclusions and to resolve ambiguities that may still exist.

Finally, it should be stressed again that the limit of any scientific provenancing strategy is the representativity of the material base used as a reference. From a theoretical point of view the latter cannot be too large. It is important that any future fieldwork provide samples that are large and neither altered nor contaminated in order to allow analysis by different scientific techniques. Moreover, full documentation should be made available on the exact origin of the samples, so that archaeological or geological shortcomings of the reference material can be detected.

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The authors are greatly indebted to the National Fund for Scientific Research (NFWO), the Interuniversity Institute for Nuclear Sciences (IIKW), the Fund for Collective Fundamental Research (FKFO), and the Research Council of the University of Ghent for their extensive financial support.

We are also indebted to the Greek, Turkish, and Italian authorities for their cooperativeness during the sampling in the marble quarries. The most valuable assistance of Professor Nuşin Asgari and Dr. E. Dolci is gratefully acknowledged. Our sincere thanks are due to Professor H. Mussche and Mrs. D. Vanhove for giving us the opportunity of participating in the exhibition "Marmer in Hellas" (Brussels, December 18, 1987–April 13, 1988) and for making it possible for us to study the artifacts discussed in the present paper. We would also like to thank Professor E. Keppens for his help during the isotopic analysis of the artifact samples.

1 N. Herz, "Isotopic Analysis of Marble," in G. Rapp, Jr., and J. A. Gifford, eds., *Archaeological Geology* (New Haven, 1985), pp. 331–351; idem, "Carbon and Oxygen Isotopic Ratios: A Data Base for Classical Greek and Roman Marble," *Archaeometry* 29.1 (1987), pp. 35–43.

2 This sampling procedure obviously introduces contaminants originating from the tools. Therefore a procedure was developed to obliterate the contamination from drilling and sawing: a full report on this is given in L. Moens et al., "Preparation of White Marble Samples for Neutron Activation Analysis," *Bull. Soc. Chim. Belg.* 95 (1986), pp. 399–406.

3 Ibid.; idem, "Identification of Archaeologically Interesting White Marbles by Instrumental Neutron Activation Analysis (INAA) and Petrography: Comparison between Samples from Afyon and Uşak (Turkey)," *J. Trace and Microprobe Techniques* 5.2–3 (1987), pp. 101–114; idem, "White Marble from Italy and Turkey: An Archaeometric Study Based on Minor- and Trace-element Analysis and Petrography," *J. Radioanal. Nucl. Chem.*, Article 123 (1988), pp. 333–348; idem, "Chemical and Petrographical Identification of White Marbles from the Mediterranean Area, I: Comparison between Carrara and Marmara Marbles," in, Y. Maniatis, ed., *Archaeometry* (Amsterdam, 1989), pp. 613–624.

4 Moens, et al., 1987 (note 3); idem, 1988 (note 3); idem, in *Archaeometry* (note 3); P. Roos, et al., "Chemical and Petrographical Characterization of Greek Marbles from Pentelikon, Naxos, Paros and Thasos," in N. Herz and M. Waelkens, eds., *Classical Marble: Geochemistry, Technology, Trade. Proceedings of the NATO-Sponsored Advanced Workshop: Marble in Ancient Greece and Rome: Geology, Sources, Commerce, Artifacts*, Il Ciocco (Italy), May 9–13, 1988 (Dordrecht, 1988).

5 Moens, et al., in *Archaeometry* (note 3).

6 Herz, 1987 (note 1).

7 Ibid.

8 Ibid.

9 P. De Paepe, et al., "Source Analysis of the Raw Material of Four Classical Marble Sculptures Using Chemical, Microscopic and Isotopic Parameters," *Proceedings of the NATO-Sponsored Advanced Workshop* (note 4).

10 *Marmer in Hellas: Van Steengroeve tot Kunstwerk*, Brussels, Gemeentekrediet van België, December 1987–April 1988 (Brussels, 1987).

11 O. Palagia, "Les techniques de la sculpture grecque sur marbre," in *Marmer in Hellas* (note 10), pp. 186–187.

12 *Marmer in Hellas* (note 10), pl. 145.

Stable Isotope Analysis of Carrara Marble: Some Questions for the Archaeologist

Susan Walker and Keith Matthews

The isotopic signature of Carrara marble has been well established in recent years by the work of Nancy Dean and Norman Herz, and of Marc Waelkens and his colleagues.[1] Through the generosity of these scholars, the British Museum has acquired isotopic data from the Carrara marble quarries (by courtesy of Professor Herz) and samples of marble from known locations in several quarries (by courtesy of Professor Waelkens). Happily, these independent measurements have been found to coincide. We may then have some confidence in a well-defined isotopic signature for Carrara marble. Indeed, it has been claimed that it is possible to distinguish isotopically Seravezza marble, used in the Renaissance, and the highly mineralized Mandria marble, from other Carrara quarries exploited in antiquity.[2] The distinction of Renaissance from Roman use of Carrara marble is not a subject I am able to pursue in this paper but I should like to note the point here as a promising subject for future research. This is a matter of considerable importance for the distinguishing of restorations to ancient works, of fakes, copies, and post-Renaissance works carved in the Roman style.

Carrara marble has a compact isotopic signature, particularly compared to the sprawling signature of Dokimeion, a stone with remarkable variation of carbon ratios, noticeable even in individual measurements.[3] The percentage of quarry samples correctly reclassified when run as unknowns in a program of discriminant (statistical) analysis was found to be consistently high (89%), suggesting good characterization of the quarries.[4] But Carrara presents a problem of overlap, notably with Prokonnesian marble, which may not be resolved by isotopic analysis, nor by a statistically sophisticated program of discriminant analysis, in which results may be assigned to a series of ranked signatures.[5] However, this difficulty may be resolved by a practiced eye, which can distinguish the fine white crystals of Carrara from the coarser crystals of Prokonnesos. More recently, the problem has been scientifically resolved by neutron activation analysis, which clearly distinguishes the two stones.[6] As an example of this difficulty of overlap, I cite the results of a substantial program of analysis of fragments from the Severan Marble Plan of Rome (fig. 1), which

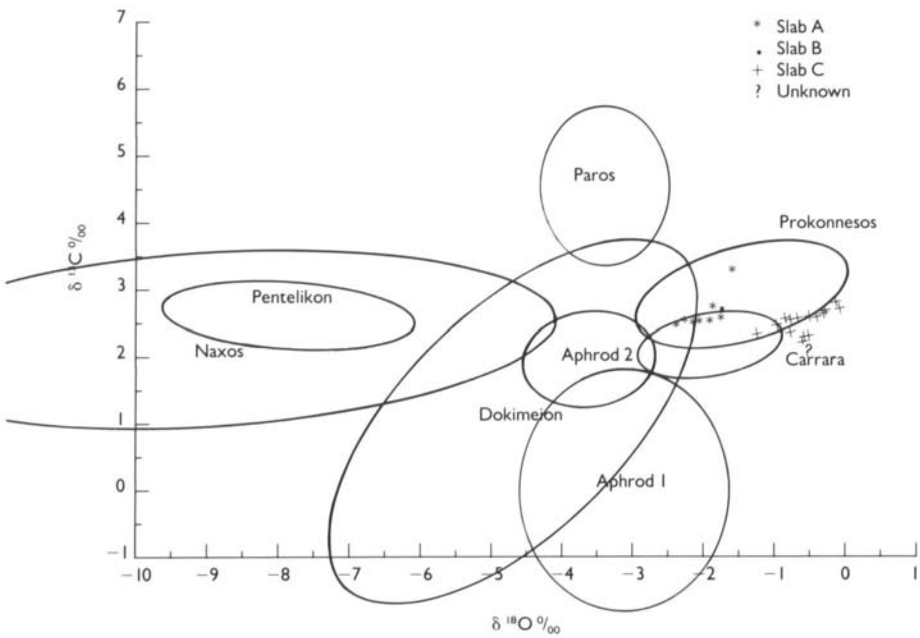


FIG. 1

Isotopic data from the Severan Marble Plan of Rome showing the signature of Carrara marble and the area of overlap with Prokonnesian.

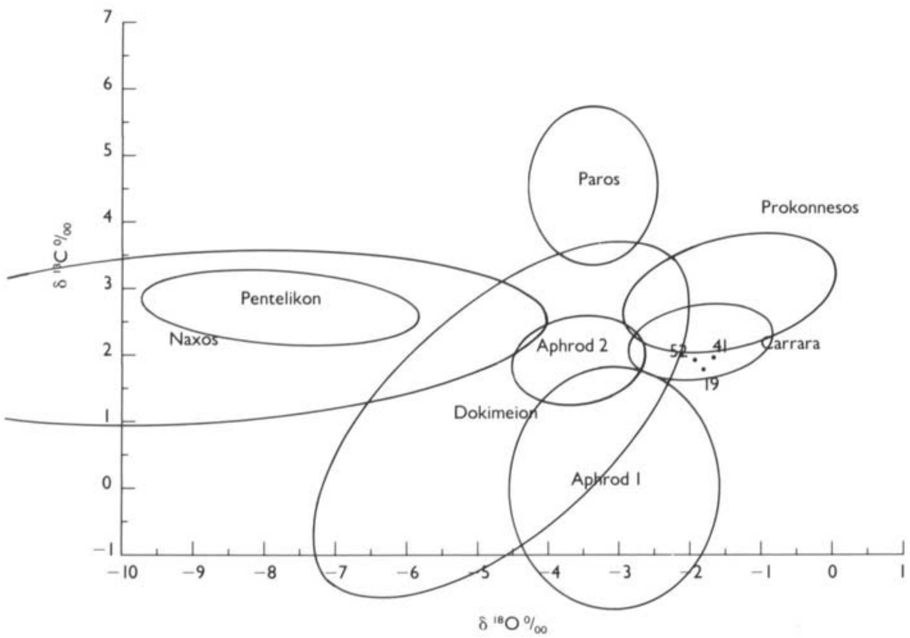


FIG. 2

Isotopic analysis of togate statues of Carrara marble from Lepcis Magna.

FIG. 3

Isotopic analysis of architectural elements from the forum at Cherchel.

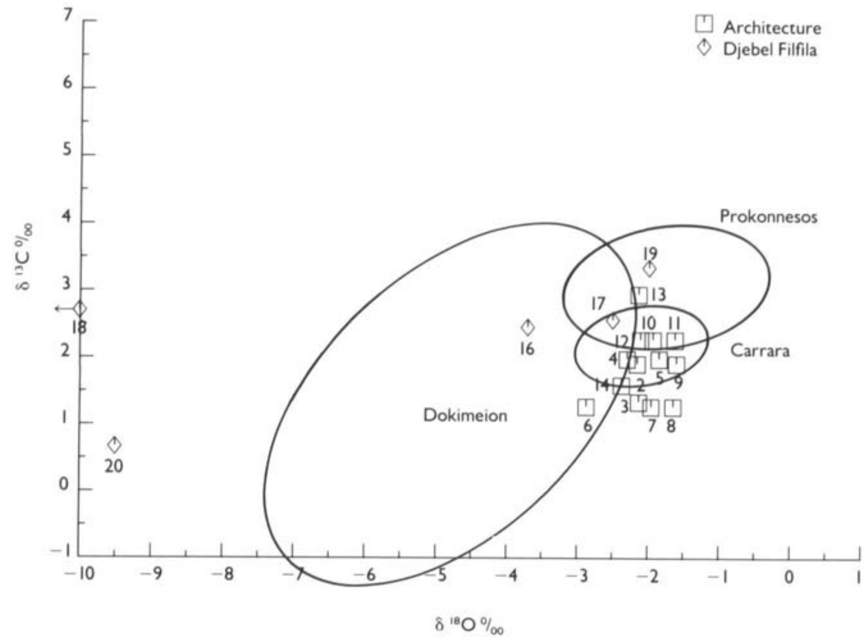
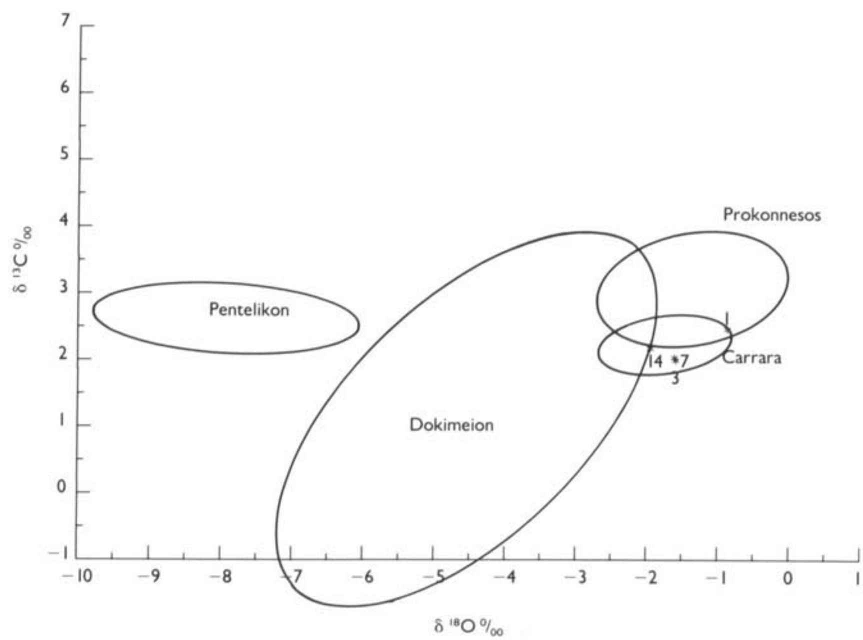


FIG. 4

Isotopic analysis of Carrara marble sarcophagi in the British Museum.



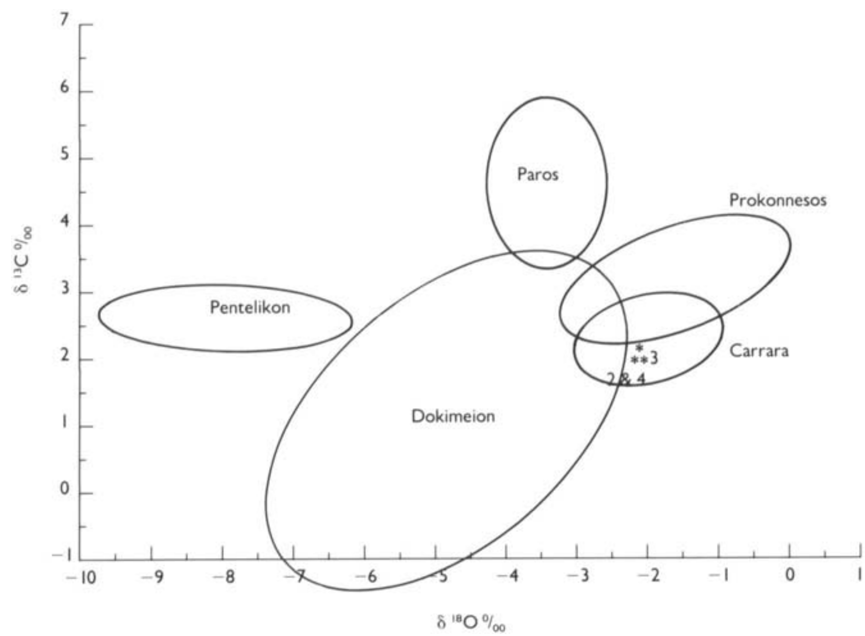


FIG. 5

Isotopic analysis of the lid-panel of a sarcophagus in the British Museum.

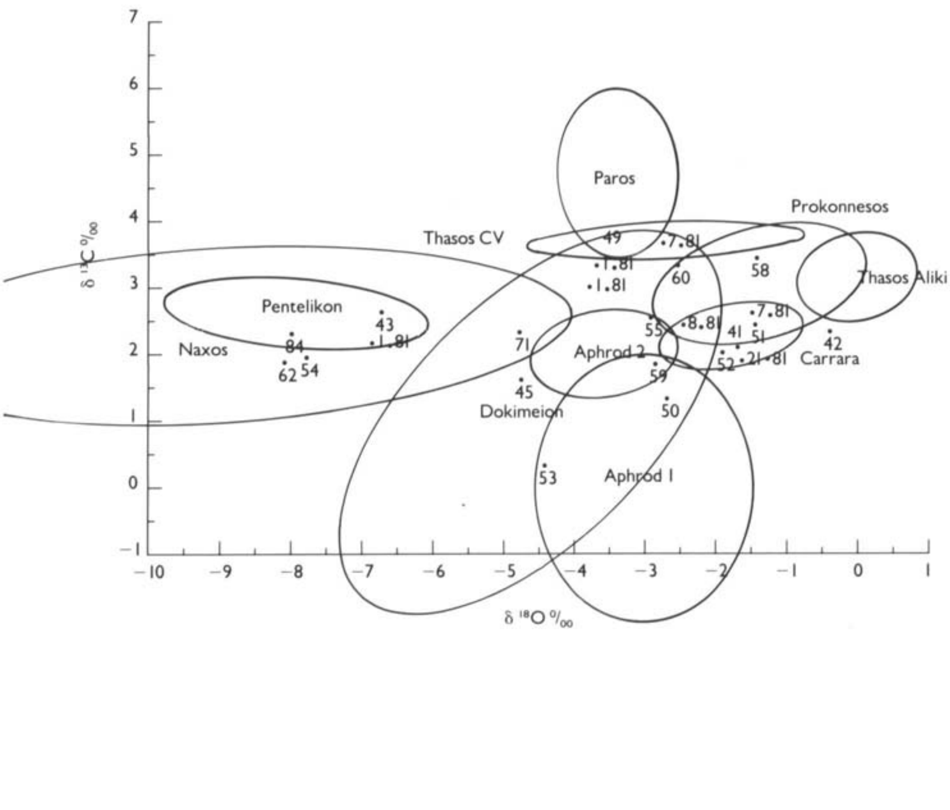


FIG. 6

Isotopic data showing the use of marble at Lepcis Magna in the first century A.D.

FIG. 7

Isotopic data showing the use of marble at Lepcis Magna in the third century A.D.

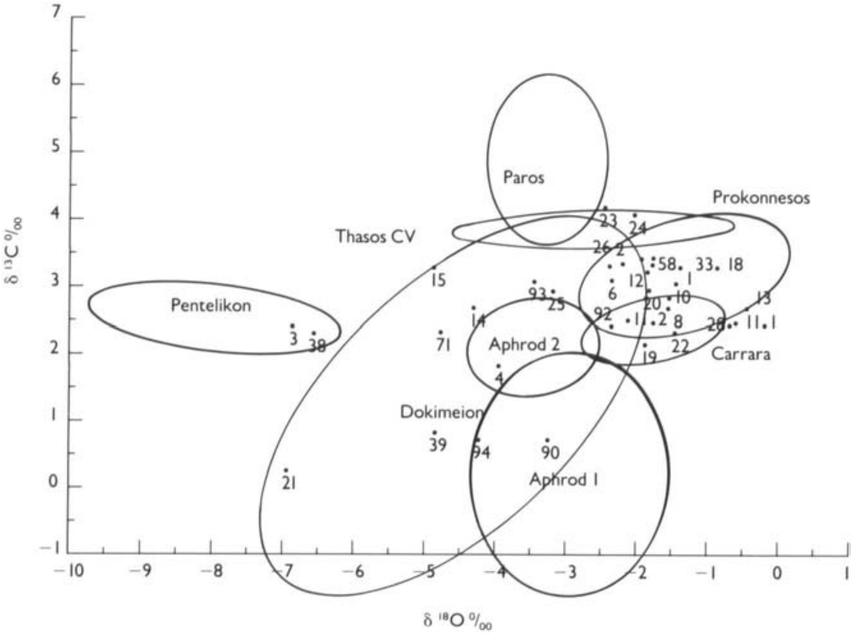
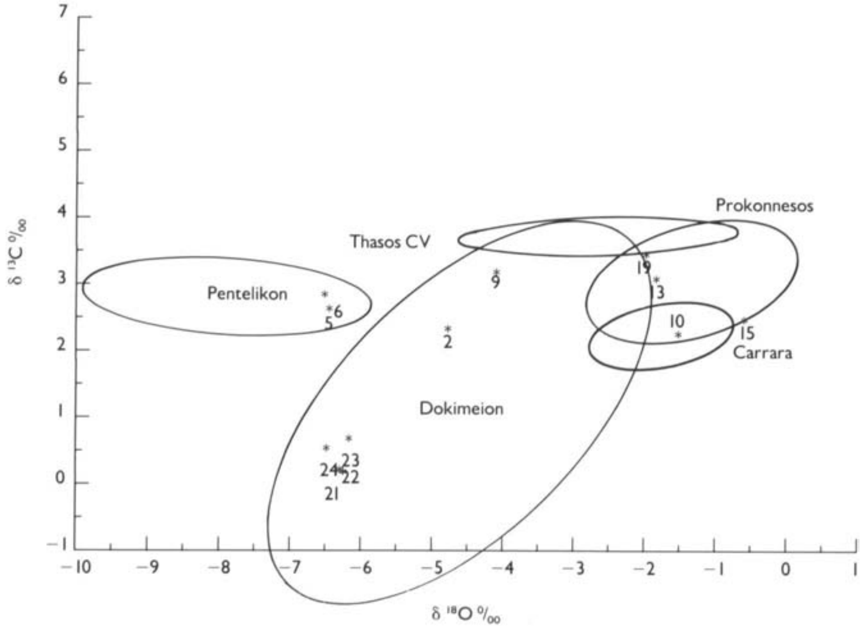


FIG. 8

Isotopic analysis of third-century sarcophagi in the British Museum.



leaves the origin of the stone unclearly identified by isotopic analysis. However, it has proved possible isotopically to distinguish horizontally from vertically set blocks and to associate fragments that must have been cut from the same block. Visual examination strongly suggests that the stone is Prokonnesian.[7]

The improved definition of the isotopic signature of Carrara marble necessitates the reappraisal of two earlier interpretations. The first concerns a group of togate statues from Lepcis Magna – two of first-century date, the third, of similar appearance, found in the Severan Forum. They were analyzed by Hafed Walda and briefly reported by Mr. Walda and myself in *Libyan Studies* 1984.[8] Then we were bewildered by these togati, which did not fall within any of the quarry signatures in the data base. Now we may claim with some confidence that these life-sized figures were made of Carrara marble (fig. 2).[9] Their quality is impressive, comparable to another set of togate figures from Lepcis, apparently made of Dokimeian marble. They are strikingly different from the flat figures found at Cyrene and dated to the Severan period by Susan Kane.[10] These, too, have been isotopically analyzed by Professor Herz and found to be of Carrara marble.

My second reappraisal concerns architectural marbles from Cherchel (Iol Caesarea, Mauritania). These were excavated by Dr. Timothy Potter with Dr. Nacera Benseddik in the forum, a site well dated to the Severan period by ceramic and numismatic evidence.[11] However, the architectural elements are clearly of much earlier date and were reused in the forum. The capitals, published by Patrizio Pensabene, compare well with those of the Temple of Mars Ultor in the Forum of Augustus at Rome.[12] Indeed, Pensabene suggested they were of Carrara marble and were sent from Italy to Mauritania along with skilled craftsmen, some of whom signed or monogrammed the matching column bases, for use in the extensive building program by Juba II, client-king of Augustus.[13] I initially doubted the identification and even now must warn of a possibility that the marble is from the quarries at Djebel Filfila in eastern Numidia (now a military base and not accessible for archaeological work).[14] But it now seems much more likely that Carrara is the origin of the stone and that the capitals were sent with masons from Italy, as Pensabene suggested (fig. 3).

My primary interest in isotopic analysis has been the identification of marbles used to make Roman sarcophagi, in an attempt to clarify the origins of the sarcophagi now in the collections of the British Museum. Several of those analyzed appear to be Carrara (fig. 4). These include a fragment of a battle sarcophagus of late second-century date and a small early garland sarcophagus found in a chamber tomb near Benghazi (Cyrenaica).[15] A striking sarcophagus portraying a young girl on her deathbed, one of a group of some six Antonine sarcophagi from Rome so similar that they appear to be products of the same workshop, is also Carrara, as is the lid of a fine large chest decorated with scenes from the life of Herakles.[16]

A lid-panel decorated with six pairs of seated Amazons, formerly in the Townley collection, was also found to be of Carrara marble (fig. 5). Samples were taken from three places to test the assertion, first made by Carl Robert, that the right-hand portion of the relief was a restoration by the sixteenth-century sculptor Guglielmo della Porta (del Piombo).[17] Observation suggested that Arthur Smith, who catalogued the lid-panel for the British Museum in 1904, was correct in his judgment that no more than minor restorations and joins were made to the relief.[18] Isotopic analysis supported Smith's view, showing the three samples to cluster within the Carrara signature, so closely that they would seem to belong to the same block.

Renaissance drawings help to explain this relief's checkered history.[19] The sarcophagus to which it belonged stood with another similar chest in the church of Saints Cosmas and Damian in the Roman Forum. Here some figures from the lid may have been drawn by Pisanello in 1431/1432. Around 1500 part of the lid-panel was drawn again, by a follower of Ghirlandaio. By about 1550 the sarcophagus was moved with its companion piece to the Vatican, where it was apparently broken up, and the lid-panel passed to the collection of Guglielmo della Porta. There it was drawn by Gianantonio Dosio before della Porta's death in 1577. Dosio's drawing stops after the fourth Amazon, where the sarcophagus was broken and there is now a straight join through the relief. It would seem that the fifth and sixth Amazons, which appear with the third and fourth on the drawing of about 1500, are now missing. Della Porta's work may then have been to tidy the breaks in the relief and to join the two sections, thus forming a shortened but symmetrical panel of six Amazons (nos. 1–4 and 7–8).

Drawing together the dates of all the items mentioned in this paper, we find two first-century statues from Lepcis Magna, one from the Severan Forum, and a series of Augustan capitals from Cherchel. The child's sarcophagus from Benghazi, which has been compared to the "Caffarelli" sarcophagus now in Berlin, may be first century, though a certain heaviness in the execution of this poorly finished work leads me to favor a Trajanic or Hadrianic date.[20] To these early examples we may add the four Antonine sarcophagi. The preponderance of early Imperial instances of the use of Carrara marble is as striking as the lack of third-century and later examples of Carrara marble sarcophagi and architectural elements. The data cited here may be augmented by other samples of architectural marble from the Flavian

Temple at Lepcis Magna, where analysis of a column gives an unequivocal result of Carrara, and samples of paving and of another column may also be Carrara (fig. 6). In a paper given at the American Institute of Archaeology meetings in San Antonio in 1986, I pointed to evidence for a shift in the use of marble, from Carrara to Prokonnesos and most likely also Thasos (for which published isotopic quarry data remains unsatisfactory) in the production of sarcophagi at Rome in the early third century A.D.[21] Data from Lepcis Magna suggests that a similar shift may be observed in the use of marble for architectural decoration (figs. 6–7).

Clearly, the pattern of use of Carrara marble needs substantial fleshing out, but a skeletal structure seems clear enough: the marble was much used for early Imperial sculpture and architecture at Rome and in the western provinces, apparently reaching a peak about A.D. 100, by which time a special bureau dealing exclusively with the reception of Carrara marble had been established at Rome.[22] Carrara would appear to have continued in favor for metropolitan sarcophagi throughout the second century A.D. By the Severan period, however, a marked preference for Greek marbles may be shown for sarcophagi made at Rome (fig. 8) and, significantly, for the Imperial program of building at Lepcis Magna. Cherchel was apparently insufficiently wealthy by Severan times to import architectural decoration in marbles from the Greek east; contemporary decoration is in limestone, or in the case of the Forum, in *spolia*.[23]

One obvious question is whether the same trend appears in other media. Imperial monuments in Rome are already being studied, but Imperial and private portraiture, datable to and flourishing in the third century A.D., cries out for attention. Here it should be noted that Susan Kane's work at Cyrene suggests that statuary marble used for togati was flourishing in the Severan period. The reasons for the import of such statues are likely to be cultural; as Kane notes, the type of figure is Roman, not Greek, and was most likely unfamiliar to sculptors trained in Greek traditions.[24] I can see no economic benefit for Cyrene in such trade, nor indeed for Luni, since the quarries at Carrara were owned by the emperor.[25] Another question is whether Lepcis Magna, in respect to its architectural decoration, is to be regarded as exceptional – a "Severan Rome," if you like – or whether a similar trend is apparent in other provincial cities. Southern France, Spain, and northeast Italy could be studied with profit. The historical question of why the apparent decline in certain types of Carrara marble should happen when it did has been explored in some detail in another paper.[26]

Notes

Susan Walker, who prepared the text of the paper, would like to thank her co-author, Keith Matthews, who carried out the analyses of many of the samples and provided the illustrations on short notice. Both authors wish to thank the Trustees of the British Museum and Dr. M. S. Tite and Mr. B. F. Cook, Keepers of the Research Laboratory and of the Department of Greek and Roman Antiquities, respectively, for their constant support. Dr. Morven Leese of the British Museum Research Laboratory undertook discriminant analysis of quarry and other samples. Dr. Hafez Walda provided samples of marble from Lepcis Magna and undertook analysis of them in 1983–1984; the results have been reassessed by Keith Matthews. Dr. Timothy Potter permitted the notification of the results from Cherchel in advance of their full publication. Amanda Claridge provided samples from the Severan Marble Plan of Rome and from the quarries at Djebel Filfila and likewise permitted notification in advance of full publication. Dr. Ruth Rubinstein assisted with references for the drawings of Sc 2299.

1 See most recently N. Herz and N. E. Dean, "Stable Isotopes and Archaeological Geology: The Carrara Marble," *Applied Geochemistry* 1 (1986), pp. 139–151. Professor Waelkens' work is not yet published.

2 Herz and Dean (note 1), p. 146, fig. 6, table 3; pp. 147, 149. E. Dolci, *Carrara Cave Antiche* (Carrara, 1980) gives a general account of the quarries, including (pp. 144–148) the evidence for ancient working of Mandria.

3 M. Coleman and S. Walker, "Stable Isotope Identification of Greek and Turkish Marbles," *Archaeometry* 21 (1979), pp. 110–111.

4 Discriminant analysis was undertaken in 1986 by Dr. Morven Leese.

5 In this respect the findings of the British Museum team are at variance with Herz and Dean (note 1), p. 151.

6 E. Mello, D. Monna, and M. Oddone, "Discriminating Sources of Mediterranean Marbles: A Pattern Recognition Approach," *Archaeometry* 30.1 (1988), pp. 102–108, esp. p. 107, fig. 1.

7 The samples were submitted for analysis by Amanda Claridge and Dr. Lucos Cozza. The stone was visually identified by Amanda Claridge.

8 H. Walda and S. Walker, "The Art and Architecture of Lepcis Magna: Marble Origins by Isotopic Analysis," *Libyan Studies* 15 (1984), pp. 81–92, esp. p. 83, fig. 2, and p. 84.

9 H. Walda and S. Walker, "Isotopic Analysis of Marble from Lepcis Magna: Revised Interpretations," *Libyan Studies* 18 (1988), pp. 55–59, esp. p. 55 and p. 56, fig. 1.

10 N. Herz, S. E. Kane, and W. B. Hayes, "Isotopic Analysis of Sculpture from the Cyrene Demeter Sanctuary," in P. A. England and L. van Zelst, eds., *Application of Science in Examination of Works of Art: Proceedings of the Seminar: September 7–9, 1983* (Boston, Mass., The Research Laboratory, Museum of Fine Arts, 1986), pp. 141–150, esp. pp. 149–150.

11 S. Walker, "The Architectural Marbles," in T. W. Potter and N. Benseddik, *Excavations at the Forum Site, Cherchel, 1977–1981*. Bulletin d'Archéologie Algérienne, Suppl. 3 (Algiers, forthcoming).

12 P. Pensabene, *Les Chapiteaux de Cherchel: Etude de la decoration architectonique*. Bulletin d'Archéologie Algérienne, Suppl. 3 (Algiers, 1982), pp. 20–22, nos. 19–24.

13 Pensabene (note 12), pp. 21, 70, 72.

14 Surface samples of recently exploited marble from Djebel Filfila were analyzed at the British Museum in 1983; one of the five results coincided with the isotopic signature of Carrara marble.

15 Battle sarcophagus: GR 1951.3–6.1, S. Walker, *A Catalogue of Roman Stone Sarcophagi in the British Museum* (1990), pp. 15–16, no. 2. Garland sarcophagus: Sc. 2325, ibid., p. 34, no. 37; D. M. Bailey, "Crowe's Tomb at Benghazi," *BSA* 67 (1972), pp. 2–12, esp. p. 10; J. Huskinson, *Corpus Signorum Imperii Romani, Great Britain*, vol. 2, part 1 (London, 1975), p. 51, no. 91, pl. 35. For the Italian parallels, see H. Brandenburg, "Der Beginn der Stadtrömischen Sarcophagproduktion der Kaiserzeit," *JdI* 93 (1978), pp. 277–327.

16 "*Conclamatio*" sarcophagus: Sc. 2315, Walker (note 15), pp. 17–18, no. 6; G. Koch and H. Sichtermann, *Römische Sarkophage* (Munich, 1982), p. 112, n. 37 (bibl.). Herkules: Sc. 2300, Walker (note 15), pp. 22–23, no. 15.

17 Sc. 2299, Walker (note 15), pp. 21–22, no. 14; C. Robert, *Die Antiken Sarkophagreliefs*, vol. 2. *Mythologische Cycklen* (reprinted, Rome 1968), p. 94, no. 78, fig. 32. See also P. P. Bober and R. O. Rubinstein, *Renaissance Artists and Antique Sculpture* (Oxford, 1986), pp. 178–179, no. 142.

18 A. H. Smith, *A Catalogue of Sculpture in the Department of Greek and Roman Antiquities, British Museum*, vol. 3 (London, 1904), p. 305.

19 Bober and Rubinstein (note 17), pp. 178–179.

20 For the comparable material from Italy, see Brandenburg (note 15).

21 "Recent Work in Stable Isotope Analysis of White Marble at the British Museum," in J. Clayton Fant, ed., *Papers in Roman Marble Quarrying and Trade* (Oxford, 1988), pp. 117–124.

22 *CIL* VI.8484–8485.

23 Walker (note 11); Pensabene (note 12), p. 73.

24 Herz, Kane, and Hayes (note 10), p. 149.

25 Economic stimulus for Lepcis Magna is suggested by Herz, Kane, and Hayes (note 10), p. 150. For the view that Imperial quarries did not benefit local economies, see J. Clayton Fant, "Dio Chrysostom's *poikiloi lithoi* of Teos: An Archaeological/Geological Survey of the Roman Imperial Marble Quarry," in S. Walker and A. Cameron, eds., *The Greek Renaissance in the Roman Empire. BICS*, Suppl. 55 (1989), pp. 206–217.

26 S. Walker, "From West to East: Evidence for a Shift in the Balance of Trade in White Marbles," in N. Herz and M. Waelkens, eds., *Classical Marble: Geochemistry, Technology, Trade. Proceedings of the NATO-Sponsored Advanced Workshop: Marble in Ancient Greece and Rome: Geology, Sources, Commerce, Artifacts*, Il Ciocco (Italy), May 9–13, 1988 (Dordrecht, 1988), pp. 187–196.

Ancient Techniques of Making Joins in Marble Statuary

Amanda Claridge

For more than eight hundred years the ancient art of making joins in marble statuary was a necessary, and important, sculptural skill. Sculptors started piecing their work as early as the sixth century B.C. – almost as soon as they began making freestanding statuary of any size – and the practice continued throughout antiquity. Indeed, at times, notably in the last two centuries B.C. and the first century A.D., the ability to make a good join in a wide variety of sculptural situations is likely to have been far more useful to the average ancient sculptor than his ability to achieve an ambitious composition in a single block.[1] Whether skillful joining ranked on a par with monolithic work is doubtful; monolithic works in their larger and more complex forms have the power to inspire a particular awe.[2] But that is not to say that joining did not witness its own technical triumphs.

To appreciate a triumph, one has to appreciate the nature of the challenge. In the postantique world, the art of joining has had a very different history, beginning and ending at best as an exercise in restoring antique works and at worst as an admission of defeat. By now, nurtured as we are on late nineteenth-century concepts of the integrity of materials in art, we are ill-disposed to view any join with favor, let alone recognize its intrinsic qualities. Beyond the joins on the Archaic korai from the Akropolis, the subject has hardly received any attention at all.[3] We have to start practically from scratch.

Marble is extremely heavy; it weighs around 2.7 tons or more per cubic meter (about 170 lbs. per cubic foot). The first consideration in joining, therefore, is the angle at which the join has to be made: the disposition of the weight of the piece being added. Some joins are gravity-assisted; they lie in a horizontal plane and the weight of the addition functions to keep the join together. Many more joins, however, are gravity-defying, angled off the horizontal, and the success of the join is then essentially a question of the power of the adhesive or other kinds of fixing employed, relative to the specific gravity of the piece to be held in place. To some extent, the shape of the joining surfaces can constitute the principal fixing, by being made to interlock with one another under stress, as in wood- or metal-working, but the possibilities are strictly limited: although marble is admirably resilient compared with other stones, it shares their general lack of tensile strength. The more slender and isolated the forms are into which it is carved, the less able it is to withstand shocks, tremors, or any sort of strain, including that of its own weight. This is the second consideration: just as there are some elements difficult or impossible to execute in a single block without leaving some support, so there are elements that cannot be joined without recourse to materials stronger than marble. Support has to be built into the join in the form of a rod or dowel.

In applying these broad guidelines among the mass of ancient evidence, some basic difficulties arise. First of all, although all joins by definition involved two elements and thus there should be two sides to the evidence, it is extremely rare that both elements are preserved. We have lots of bodies but few arms, lots of heads but not those that fit the bodies, and so forth. And when both elements *do* survive, they have usually been reassembled, without a detailed record and in a fashion that renders their precise relationship, as well as any internal evidence, invisible.

Secondly, we are regrettably ill-informed regarding much of the secondary apparatus of joining. Few traces of ancient cements and adhesives may be expected to have survived, but fewer still appear to have been analyzed and their properties tested (see Appendix, below): what might be quite different products could look very much alike to the naked eye, especially in their decayed state. The same goes for lead and lead solders; although more readily detectable than other kinds of fixing for marble, they have not been investigated in detail. Consequently, the strength of available "glues" has to be inferred; and when the inference itself is based on conjectural weights of missing additions, the possible pitfalls are obvious.

As for pins, rods, and dowels, some could have been of wood, in which case they will have long since perished; most would have been of metal, especially iron, and in that case the dynamics of their destruction over a period of two thousand years are more complicated – and potentially more significant – than their relative durability. In researching this paper, it was a surprise to me to discover how many iron dowels probably survived antiquity and the middle ages, only to fall prey to later restorers or modern conservators who, with the best of motives, removed them and then, equally conscientiously, filled in the holes. It was also surprising to realize just how much of the damage supposedly wrought by an actively impermanent metal such as iron might more plausibly be attributed to later generations in search of scrap metal. In the same way that clamps and dowels were robbed from ancient buildings, the joins on ancient statues were attacked – at less risk

FIG. 1

Adding the head on an Archaic kore. "Butting" socket-and-tenon join. About 500 B.C. Drawing by author (based on Athens, Akropolis Museum 674).

to life and limb – for the sometimes sizable amounts of iron they contained. One wonders whether one of our fundamental preconceptions about joining – that it was foolhardy if not professionally irresponsible to combine iron and stone – is not misguided; the ancient world may have seen things differently. Like everything else about the sculptor's craft, a great deal would have depended on the quality of the materials, the quality of the workmanship, the nature of the join, where the statue was to be set up, and what provision was made for its protection and maintenance. Perhaps one should speculate instead on how long some of the more adventurous monolithic statues lasted: did they survive intact any longer than their non-monolithic counterparts? If the numbers of ancient repairs are any indication, there was probably not much to choose between the two, and the odds may even have been in favor of joining and using metal.

Last but not least, scholarly indifference to joining has resulted in an understandable but frustrating dearth of published photographs in which joins are clearly visible. In what follows, the choice of examples has often been dictated by that simple fact, or by the no less simple circumstance that I happen to have photographed a join myself. Sometimes, however, I have just taken the liberty of making a drawing whenever I think it suits the purpose better.

ARCHAIC PRACTICES

Archaic sculptors were pioneers in the field of joining and their practices serve as an appropriate introduction. Although the range of figure types they produced was modest compared with that which faced later sculptors, many of the basic situations of their joins remained the same, providing a convenient index for comparative analyses. They added heads from the bottom of the neck, and forearms or hands where they emerged from a sleeve or folds of clothing, both continuing for centuries to be the commonest forms of additions. They also had occasion, like many later sculptors, to add pieces to the tops of heads, to attach sections of drapery, and to make statue bodies from two main blocks. These are very different kinds of joins, differing greatly in the weight and shape of the addition, differing in the angle at which it was being added, and as time went by the differences became increasingly associated with differences in techniques. But Archaic sculptors tackled them all in more or less the same fashion, with a degree of conformity not met with again until the Late Roman period, and then in a radically different sense. What happened in the intervening years is primarily the question of adhesives, followed closely by that of metal dowels. Archaic sculptors clearly made little use of either, placing their faith predominantly in the marble itself and a tight fit, in a manner strongly reminiscent of woodworking.

FIG. 2

Archaic kore, right forearm. Slightly reduced socket-and-tenon join. About 500 B.C. Athens, Akropolis Museum 594 (from Schrader, pl. 77).

FIG. 3

Archaic kore, right forearm. Squared socket-and-tenon join. About 500 B.C. Athens, Akropolis Museum 615 (from Schrader, pl. 82).

Where a tight fit was not enough, they employed long pins like headless nails, and where marble was not enough, they were in trouble.

To add a head (fig. 1), a flat surface was first prepared on the top of the main block, with a square or rectangular socket in the middle, smaller than the area of the join.[4] The position of the socket was then countermarked on the underside of the head block, whose extra height equaled the depth of the socket, and the excess stone at the sides was trimmed away to form a closely matching tenon. This and the weight of the head itself constituted the principal fixing, with a thin bond of fine cement, probably ordinary lime mortar,[5] to fill any slight gaps. One sculptor allowed a bit more space between the socket and tenon and fed lead in through a hole drilled from the back of the shoulders, presumably laying the work on its face in order to do so, and drilled another hole right through the join to insert an iron pin, which ended on the front of the chest.[6] Another sculptor may have used lead and/or two pins, run diagonally into the tenon from the top of each shoulder.[7] Why lead rather than cement? And why a cross-pin as well? Was it simply that lead was likely to be more durable and waterproof in the open air, where rainwater might infiltrate the join, or did the choice also have something to do with when the join was made? It could have been made at any stage in the work, perhaps right at the beginning to facilitate layout and surely before the final details were carved, so as to

FIG. 4

Archaic kore, right forearm. Socket-and-tenon join with horizontal cross-pin. About 500 B.C. Athens, Akropolis Museum 600 (from Schrader, pl. 23).

ensure their proper correspondence at the junction. But to do extensive working with the head block mounted in place would have been difficult unless it was solidly anchored. A mortar bond might easily loosen under repeated blows; perhaps lead was more resilient, particularly with a cross-pin to reinforce it.

Arms extended from the elbow and hands from the wrist display a similar preference for socket-and-tenon joins, very deep and closely fitted. Many had a recessed step in the socket wall and a proportionately reduced tenon (fig. 2).[8] Sometimes the reduced arrangement was squared in shape, as on heads (fig. 3),[9] presumably to prevent the arm turning in its socket. Cross-pinning was frequent, not just when the arm or hand projected at a lowered angle, where its

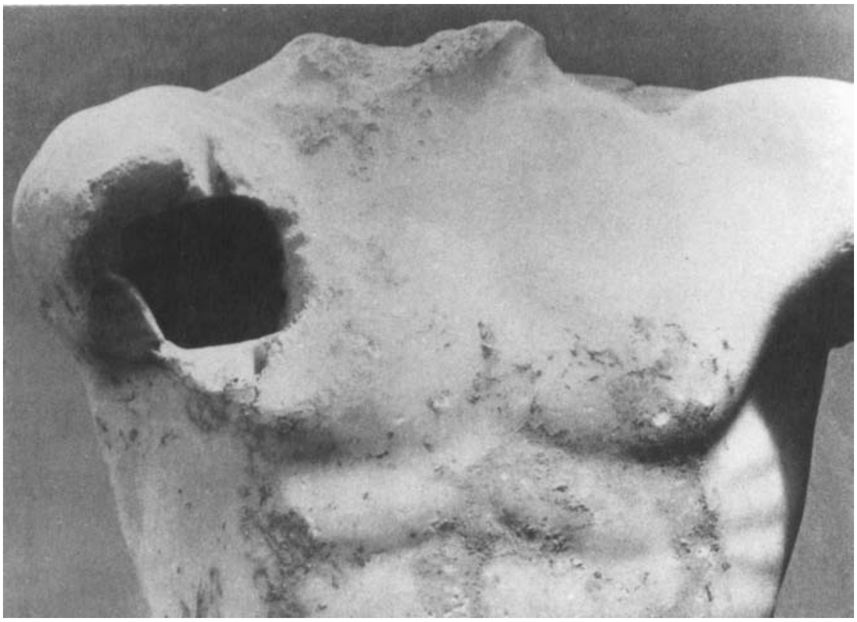


FIG. 5

Archaic warrior, right arm. "Butting" socket-and-tenon join with vertical cross-pin. About 470–460 B.C. Athens, Akropolis Museum 599 (from Schrader, pl. 130).

principal function could obviously have been to prevent the addition from falling out, but also on arms at right angles or higher, where it could have been intended equally to counter torsion. The cross-pins ran right through the joins, horizontally (fig. 4)[10] or diagonally.[11] An unusual instance of an arm added at the shoulder (fig. 5) employed a butting socket-and-tenon pinned vertically.[12] Some of the cross-pins may have been set in lead,[13] but there is no sign of it being used for the join as a whole. Either the angle and situation of the join were considered adequate protection, or such a technique was too awkward, or it was simply that arms and hands – unlike heads – were always fully carved and finished before the join was made, needing no further working.

A relatively substantial addition to the top of a head[14] was attached by shaping the underside of the added piece as a strongly concave hollow, which fitted like a cap over a matching convex surface on the head beneath. On another head[15] a shallow flat-bottomed socket was prepared, keyed for cement but also provided with a hole for a vertical pin. Even pieces at the ends of drapery folds were added with reduced socket-and-tenon arrangements, cross-pinned in various ways.[16]

Few straight butt joins were made and, when they were, the provision for their fixing appears cautious in the extreme.[17] A major horizontal butt join between the two blocks that formed the body of the kore Akropolis 682 (fig. 6a)[18] was a particular challenge. Two deep cavities were made in each block to form a pair of enormous sockets, of which one is quite well preserved (fig. 6b).[19] Its evidence is confusing, to say the least. Schrader observed (1) that, although C contains lead, the drill-holes ABCDE were not for pouring lead since B and C are blocked at their inner ends by cement; (2) that a thick layer of lead was introduced to the empty socket with the block in

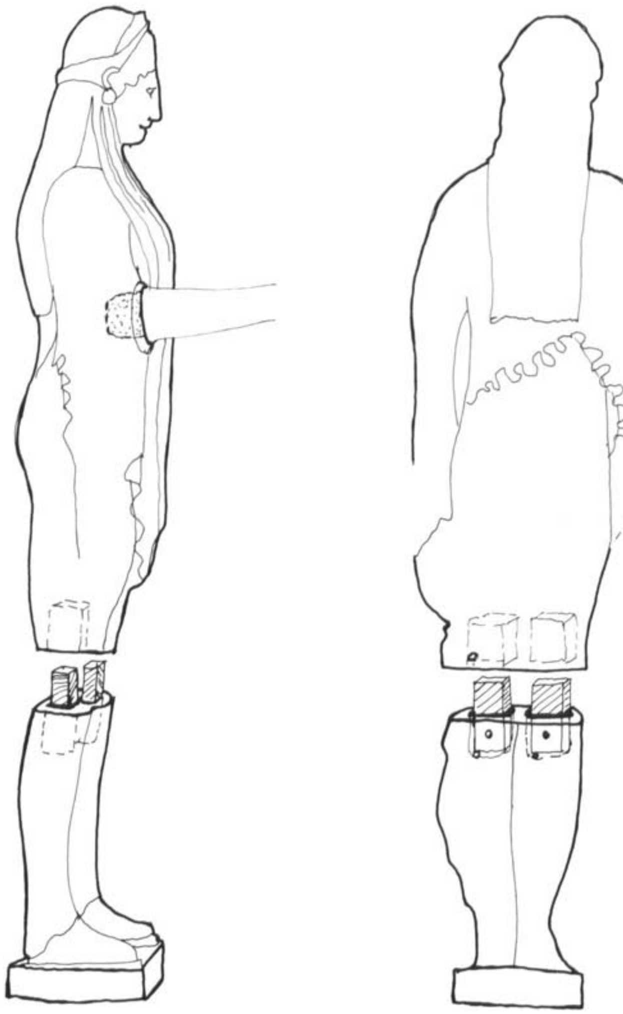


FIG. 6a

Archaic kore, body made from two blocks. Butt join with two large dowels. About 525 B.C. Athens, Akropolis Museum 682. Drawing by author.

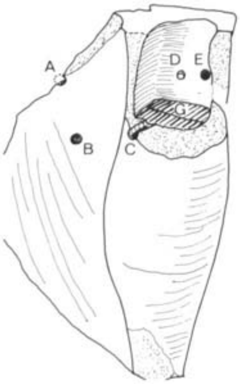


FIG. 6b

Detail of the kore, figure 6a. Dowel hole at right knee (redrawn by author after Schrader, fig. 56).

an upright position, to provide a footing for the large dowel (of bronze, represented by the imprint G and bronze stains); (3) that a hole through a joining fragment of the back wall of the socket, on a level with D and E and with A, contains traces of bronze, but again has cement blocking its inner end; and (4) that the corresponding socket in the upper block also bears traces of cement, and that, therefore, the cavity around the dowel was apparently filled only with cement. The holes ABCDE must have had some intended purpose, however, and one wonders whether A and its equivalent opposite D and E were in fact for bronze cross-pins; whether B and C were vent-holes for lead; whether, given the size of the socket, the dowel was not as small as imprint G and not of bronze but of hard wood;[20] and whether the cement is residual, finding its way from the upper socket into the lower one only after the dowel and its fixings had decayed. That is, the dowel – set on a bed of lead, sheathed and soldered in lead, and cross-pinned at its lower end, set in cement at its upper end – rotted; the bronze stains on the lead in the bottom derive from the cross-pin above; the lead lining detached itself from the walls of the socket and collapsed inward, allowing cement from the upper socket to penetrate behind. With the break-up of the statue, the loose lead was lost. This interpretation is by no means satisfactory,[21] but if nothing else it is an object lesson in how much of the apparatus of ancient joins, when not primarily of marble, can be conjectural. Why such complicated apparatus – whatever it really consisted of – was used instead of the otherwise ubiquitous marble socket-and-tenon is another matter. The dimensions of the respective blocks may not have permitted any choice: there was not enough marble to form a suitable tenon. But assuming for the sake of argument that there was, a socket-and-tenon arrangement at knee level on so top-heavy and tapering a figure may have struck even an Archaic sculptor as too much to ask of marble.

That Archaic techniques in general expected too much of the limited tensile strength of marble can be appreciated from the manner in which the joins have broken. Heads have snapped off not across the neck, normally the vulnerable point, but across the top of the still more vulnerably reduced tenon, which remains firmly gripped by its socket. Most of the reduced tenons on arms and hands are also still in their sockets, having snapped at the point where the weight emerged unsupported, no less vulnerable than they would have been in monolithic form. In the case of thicker tenons, the correspondingly thinner outer wall of the socket has often fractured, too. And where a cross-pin was inserted, the breaks have found the further weakness created by the transverse hole. Arms and hands at lowered angles have sometimes fared slightly better – or at least their sockets have – perhaps because the weight pulled more away from than across the join and the cross-pins, which held the tenons in place, gave way first.

FIG. 7

Archaic kore, right forearm. Reduced socket-and-tenon join with horizontal cross-pin and pin on axis within tenon. About 485 B.C. Athens, Akropolis Museum 685 (redrawn by author after Schrader, fig. 61).

By the end of the Archaic period some sculptors had already begun to modify their methods. The tenon on one head, although still undercut to allow the outer edges to butt together, was rounded in shape and proportionately much larger.[22] A forearm was set in with two short cross-pins instead of one long one.[23] And another forearm (fig. 7)[24] apparently had a pin inserted on axis inside the tenon as well as a cross-pin, a modest but possibly significant pointer to a more complex future in which metal comes to the sculptor's aid in a variety of roles, not only keying a join and supplementing inadequate adhesives but as an integral element in the structure, reinforcing and supporting where marble would fail. Metal was not used indiscriminately, however. Most post-Archaic sculptors continued to make the maximum use possible of marble wherever the circumstances of the join allowed, and heads are an obvious case in point.

HEADS

The basic appeal of a butting socket-and-tenon join of Archaic type is that if the line of the join has to be visible, visibility can be reduced to the minimum. Long hair falling onto the shoulder, or a veil, was probably what encouraged the technique in the first place, and later statuary was not without its equivalent dilemmas. But later sculptors approached them, as they did easier types of heads, on different principles.

When the evidence picks up again, in the second half of the fourth century B.C., the guiding rule was clearly not to reduce the tenon at all. On the contrary, it was made as large and heavy and therefore as robust (in relation to the weight of the head of which it formed part) as was compatible with the socket that could be hollowed out in the torso. Tenons on heads from draped statues are generally large and bulbous (fig. 8a) or large and shaped as inverted truncated cones, with a flat surface on the underside (fig. 8b).[25] They occupied the whole area of the join, coinciding with the neckline of the dress, and even extended, as on the Demeter from Knidos (fig. 9), to the outside of trailing hair or a veil.[26] Only on a nude torso (fig. 8c)[27]did a sculptor step the socket and undercut the tenon to allow a fine butt join on the outside, and there too he seems to have kept the tenon as large as possible. Furthermore, a good margin was left between all these tenons and their socket walls, to be filled with a greater quantity of cement, or in some cases with lead.[28] This presumably served to cushion the tenon rather than safely fix the join, for there are heads with evidence of cross-pins, usually a single one at the back running only a short way into the tenon.[29] Some had a substantial dowel placed vertically in the bottom of the join,[30] the principal function of which could have been just to maintain the head at a constant level should the cement decay or the lead compress under the weight[31] (though it will also have keyed the more loosely fitting arrangement against any lateral movement). There is a certain correspondence between vertical dowels and tenons with a flat underside on heads of greater, or less evenly balanced, weight.[32]

Later Hellenistic and Roman techniques diversified in that most sculptors, if given the chance, took to adding heads on nude torsos with an inverted V-shaped butt join at the top of the neck rather than a socket-and-tenon at the base,[33] and they went back to making veils butt at the rear and sides (fig. 10).[34] But the tenons on the latter are the same as those on unveiled heads, and those, although marked by considerable variety of form (fig. 11), reveal no fundamental change in principle until the later Empire. Some of the variations were probably dictated directly by the dimensions of the block used for the head, which permitted only a very shallow tenon and therefore a very shallow socket, prompting an angle as near the horizontal as possible and the head in an upright pose (e.g., fig. 11c). Relatively shallow joins are characteristic of the particularly marble-

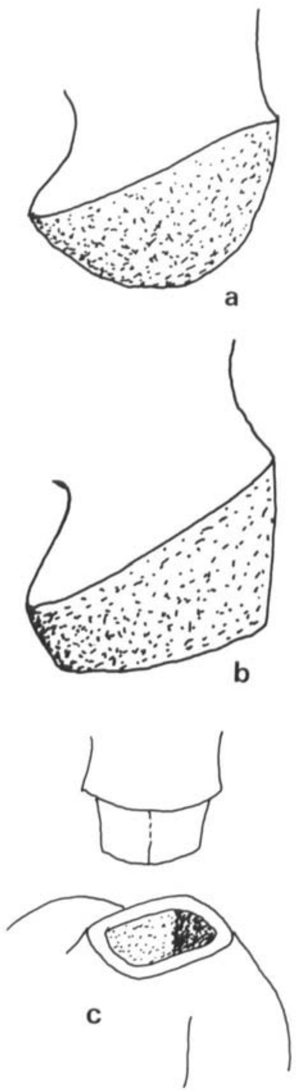


FIG. 8

Socket-and-tenon joins for heads on statuary from the Mausoleum at Halikarnassos. About 350–330 B.C. *a*, Fragment of lower neck and tenon. London, British Museum MRG 51e (see Waywell, no. 55, pl. 25). *b*, Youthful male head. London, British Museum 1056 (see Waywell, no. 46, pl. 21). *c*, Nude torso. The form of the tenon is hypothetical, based on the form of the socket. London, British Museum 1065 (see Waywell, no. 85, pl. 27). Drawings by author.

hungry years of the last century B.C. and the early first century A.D. (figs. 11a–h); deeper ones tend to predominate again in the late first and second centuries A.D. (figs. 11i–k); but it would be wrong to imply that there is any strict chronological pattern.[35] Other variations reflect the changing repertory of statuary itself, the clothing at times providing only very narrow necklines. Some sculptors simply broadened the join by incorporating an adjacent fold of drapery.[36] Others, perhaps especially on cuirassed statues, left the neck thicker so that it would overlap the edge of the socket at the back (fig. 11h).[37] Female hair often constitutes a natural buttress in this respect. Small and shallow tenons were occasionally provided with vertical dowels, [38] either to aid stability or to aid fixing, but evidence for lead, whether the join included a dowel or not, is rare.[39] Whatever the alternative fixing was, it seems generally to have improved in the course of time. Cross-pinning through the back wall was hardly feasible on shallow joins anyway, but is exceptional on deeper ones, too.[40]

FIG. 9

Demeter from Knidos. Veiled head, with solid tenon. About 300 B.C. London, British Museum 1300 (redrawn by author after Ashmole, *JHS* 71 [1951], pl. 9b).

In the later Empire matters are complicated somewhat by the growing likelihood of reuse. There are some very shallow tenons with large rectangular dowels (e.g., fig. 11m), which may have been determined by an existing socket, which the sculptor was loathe to deepen in old marble, or by similar reservations about creating a socket on a statue that originally had its head carved in one piece. On the other hand there are other tenons (e.g., fig. 11n) that are also practically butt joins, at sharply inclined angles, without a dowel of any kind.[41] That is, the technical reality for some sculptors was that self-locking, gravity-assisted socket-and-tenon arrangements could be dispensed with since their principal function was to fix the join securely; that role might now be entrusted with confidence to a powerful adhesive. Attitudes to the basic formula could change, and it is possible that the sculptors who made shallow joins with large metal dowels did so not just to keep the head in place, though they naturally did that too, but because the dowel would help to reinforce the neck.

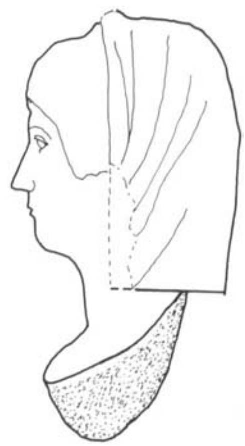


FIG. 10

"Agrippina" from Velleia. Veiled head, with partially butting tenon. About A.D. 50. Parma, Museo Nazionale di Antichità 830 (redrawn by author after Saletti, *Il ciclo statuario*, pls. 5 and 6).

BODY JOINS

While generally rejected as a solution for the delicate problems of heads, butting socket-and-tenon joins found their natural place on a larger scale lower down the body, when making a statue in two blocks. The method may not have been advisable on an Archaic kore at knee level, but it came into its own on later figure types wherever there was enough stone to form a suitably deep and substantial tenon on the upper block and thick socket walls on the lower. There is a possible example among the Mausoleum statuary, joining a colossal draped female at about waist height,[42] and numerous instances can be found among cuirassed statues

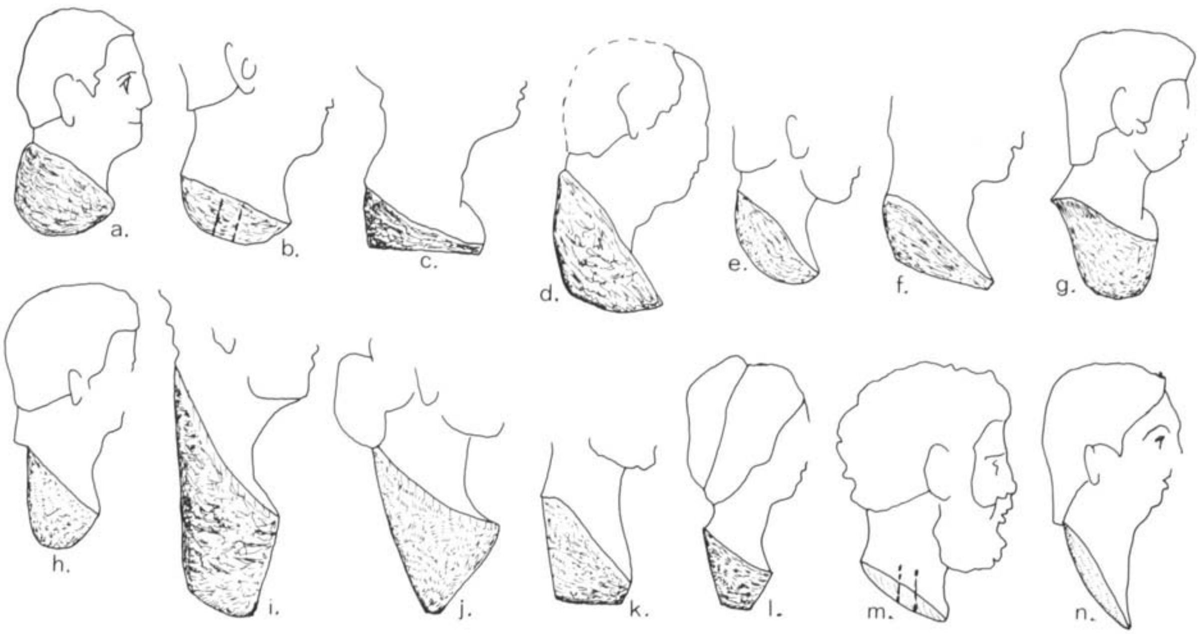


FIG. 11

A selection of tenons on separately carved heads of the Roman period. *a*, Male portrait, about 75–50 B.C. Ephesos, Selçuk Museum 2559 (Inan and Alföldi-Rosenbaum, no. 122, pl. 101). *b*, Male portrait, about 100 B.C. Delos, Museum A 4193 (Michalowski, no. 15, pl. 32). *c*, Female portrait, about 100 B.C. Delos, Museum A 4196 (Michalowski, no. 16, pls. 33–35). *d*, Male portrait, about 25 B.C., from Priene. London, British Museum 1152 (see Inan and Alföldi-Rosenbaum, no. 204, pl. 112). *e*, Augustus. Rome, Conservatori 2394. *f*, Julio-Claudian prince. Ephesos, Selçuk Museum 2558 (Inan and Alföldi-Rosenbaum, no. 19, pl. 16). *g*, Claudian prince. Edirne, Museum 1758 (Inan and Alföldi-Rosenbaum, no. 34, pl. 27). *h*, Julio-Claudian prince. Aquileia, Museo Archeologico PG 3 (V. S. M. Scrinari, *Museo archeologico di Aquileia. Catalogo delle sculture romane* [Rome, 1972], no. 184). *i*, Nerva, from Cyrene. London, British Museum 1404 (E. Rosenbaum, *Cyrenaican Portrait Sculpture* [London, 1960], no. 23, pl. 19). *j*, Sabina(?). Aphrodisias, Geyre Museum 68.341A (Inan and Alföldi-Rosenbaum, no. 39, pl. 43). *k*, Hadrian(?). Izmir (Bashmahane), Museum 4587 (Inan and Alföldi-Rosenbaum, no. 38, pl. 42). *l*, Severan female. Cyrene, Museum of Antiquities (lost) (after E. Rosenbaum, *Cyrenaican Portrait Sculpture* [London, 1960], no. 87, pl. 55). *m*, Septimus Severus. Rome, Capitolino Nuovo 2309 (A. M. McCann, *MAAR* 30 [1968], no. 4, pl. 24). *n*, Severan female, from Sardis. Cambridge, Fitzwilliam Museum (Inan and Alföldi-Rosenbaum, no. 168, pl. 127). Drawings by author.

and semi-draped nudes of early Imperial date.[43] On some cuirassed statues (fig. 12)[44] the join was made at the bottom of the cuirass skirt, just above the bare legs, in which case the usual arrangement was reversed, with the socket in the upper block and the tenon on the lower.

Post-Archaic sculptors still had to resort at times to the more troublesome solution of a butt join with vertical dowels, but later solutions were, predictably, less cumbersome than Akropolis 682. An equestrian statue from the Mausoleum, for example, in contrast to the draped female noted above, has a flat horizontal surface for the attachment of the upper torso of the rider,[45] perhaps for lack of marble to make a tenon, but perhaps because it was an inherently unstable weight. In the center of the joining surface is a large rectangular socket for a sizable vertical dowel,[46] apparently of iron and set in lead. The lead was introduced, after the upper block was mounted in place, by way of a channel running in from the outer edge of the join. The upper end of the dowel could also have been set in lead, by fixing it into the upper block before the join was closed. On the Venus de Milo (fig. 13),[47] whose naked upper half was made in a finer quality of marble than her lower half, the horizontal butt join was more lightly equipped. The blocks were keyed together by two small iron dowels situated toward the outer edges of the join and therefore hardly intended to counter any serious imbalance: if there had been enough marble, a socket-and-tenon would have done the job just as well. Lead was fed in down the full length of the dowels in a single operation, after the join was closed, by holes drilled through the drapery that forms part of the upper block.

ARMS

In the mid-second century B.C., a vertical join for the whole of the draped

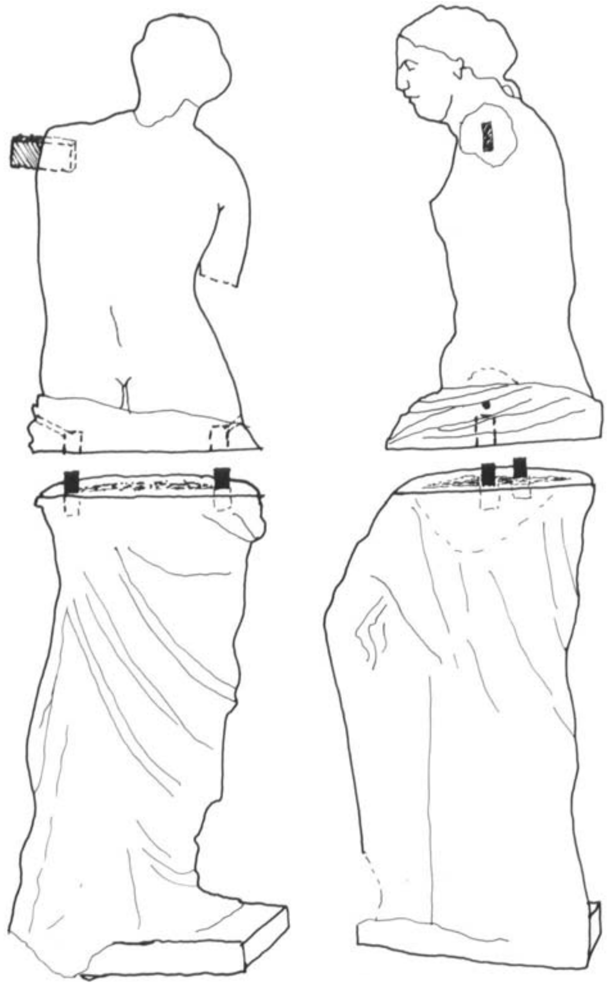


FIG. 12

Cuirassed statue, body made from two blocks. An inverted socket-and-tenon join. About A.D. 100. Drawing by author, interpreting the joins on Rome, Museo Nazionale Romano 108241, of which only the head and upper body survive (redrawn by author after Stemmer, pl. 41).

FIG. 13

Venus de Milo. Body made from two blocks, with a butt join keyed by two small dowels. About 150–125 B.C. Paris, Musée du Louvre. Drawing by author.

right arm of Despoina at Lykosura, the arm hanging beside the torso and flexed at the elbow, was made as a butt join with wedge-shaped socket-and-tenon arrangement at the shoulder.[48] Three hundred years later, for reasons best known to himself, a sculptor in North Africa attempted something similar for the lowered right arm on a nude statue (fig. 14),[49] although this meant that in order to slot the tenon into its socket, he had to make a gap in the mantle above and then patch it with another piece of marble. But he added the other arm, which extended into mid-air straight out from the shoulder, with the aid of one or perhaps two iron dowels.[50] In so doing, though two dowels would be unusual by his day, he did what thousands of other sculptors had done for centuries, at least since the pedimental groups on the Temple of Zeus at Olympia (fig. 15).[51] Sculptors who endeavored to retain marble as the primary apparatus, even for comparatively minor additions of the sort, were few and far between. An Athenian sculptor in the early fourth century B.C. added a lowered left forearm with a deep socket-and-tenon held in place by three short cross-pins;[52] a sculptor at Miletos in the second century A.D.[53] made a join for a hand in a manner almost indistinguishable from the Archaic forearm in figure 4. For the rest, angled joins operated on

FIG. 14

Statue of Saturn(?), right arm at shoulder. Wedge-shaped "butting" socket-and-tenon join. About A.D. 160. Sousse, Musée Archéologique. Photo: author.

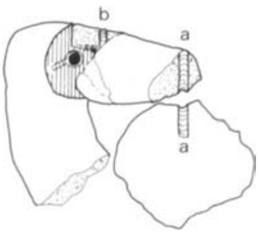


FIG. 15

Pedimental figure from the Temple of Zeus at Olympia. Butt join for forearm, with supporting dowel set in lead (through pour-hole *b*). The arm was pinned at the wrist (*a*) to the top of the head. About 460 B.C. Olympia, New Museum (redrawn by author after Treu, fig. 119).

FIG. 16

Cuirassed statue, right arm at shoulder. Large rectangular dowel. Early first century A.D. Corinth, Museum 1125. Photo: author.

principles fundamentally different from horizontal joins, and instead of worrying about the size and shape of marble tenons sculptors had to worry about the size and shape of iron dowels.

In contrast to the dowels that keyed heads and other gravity-assisted joins, which were commonly square or squarish in cross-section, the dowels that reinforced and supported arms and other gravity-defying additions passed through a phase of being distinctly rectangular. In the second half of the fourth century B.C. the tendency was so pronounced that many, like those for the forearms on the Demeter from Knidos, are more aptly described as flat oblong bars.[54] Placed so that the strain of the addition is borne by the longer axis, a rectangular shape is proportionately stronger than its equivalent volume in a square or round form, and the implications are that sculptors were either generally wary of what degree of support was needed or wary of the load-bearing properties of the iron they were using. When squarer-sectioned dowels were tried, as on a few of the Mausoleum joins,[55] a hole for a smaller but still sizable dowel accompanies the main dowel – in the same plane but some distance away – for extra strength or perhaps as a counter-pin in case the main dowel started to twist under its burden.[56]

Later practice did not abandon rectangular dowels entirely. They continued to be favored for weightier additions such as arms from the shoulder (figs. 13 and 16),[57] and one has to be prepared for their occasional recurrence in joins for forearms and hands.[58] But even rectangular shapes tend to get less exaggerated (fig. 17), while it becomes increasingly common to find square or round dowels in general use (figs. 18–19).[59] Double dowels and counter-pins are correspondingly rare,[60] and Roman dowels on the whole, whatever their cross-section, appear to have been rather smaller compared with earlier ones, some displaying further refinements of shape, such as a swelling flange in the middle (fig. 20).

Developments in the size and shape of dowels in angled joins were straightforward compared with the ever-present question of what would have been the best means of fixing them. Since the success of the join depended on the enduring strength of the iron, one might expect that every effort would be made to set it in lead, if only to inhibit oxidization. Certainly the sculptors of the pediments at Olympia (fig. 15) seem to have been at pains to do so. What is most probably a pour-hole for lead is drilled into the outer end of the dowel from the upper surface of the forearm (at *b*).[61] However, an iron pin also anchored the wrist to the top of the head (*a*). This could have been just a precaution, prompted by the convenient position of the arm and the exposed location of the statue, or it may have been done because the arm still had to be worked on after the join was made. But it might equally be an indication that lead was not really trusted. By the fourth century B.C., while some sculptors were setting both ends of their dowels in lead[62] and some may have bothered with one end only, [63] others were apparently setting both ends in "cement."[64] In a few of the latter cases oxidization was perhaps not a major concern, because the statue was to stand indoors, and cement was easier to use; in other cases the cement perhaps offered a stronger bond, but the dividing line is not clear. What is significant is that arms at lowered angles are likely to have had their dowels cross-pinned as well, whether set in lead or not,[65] which suggests that neither kind of fixing was particularly strong. If so, then presumably the lower end of the dowel would have had to be cross-pinned too, through the arm itself.

Late Hellenistic and early Roman sculptors were similarly inconsistent in their use of lead,[66] and evidence in favor of cross-pinning at lowered angles can still be found,[67] but by the second century A.D. the odds are that such supplementary fixing might be associated only with lead.[68] We find growing numbers of underhanging joins, like that in figure 17, whose dowels do not appear to have been fixed by anything other than the same extraordinarily tenacious and powerful cement that must have fixed the rest of the join.

It is tempting to seek correlations in the preparation of the joining surfaces themselves, though the equation is ephemeral. The butting surfaces of fourth-century angled joins are generally dressed with a fine claw chisel, or smoothed and then roughened with light blows of a fine point, which comes to the same thing.[69] By the Roman period they can be anything from very smooth to very rough; large scoops out of the surface or sharp gouges; sometimes they are strikingly different in two joins on the same statue (figs. 21a–b). To give the later craftsmen the benefit of the doubt, this variety could reflect a wider range of adhesives and a calculated choice in the type, or amount, to use for particular purposes. It is noticeable also that, where sculptural form permitted and it was possible to make a shallow socket rather than a straight butt join, the sockets vary in profile and depth. In fourth-century work they are minimal or nonexistent,[70] later practice was often to make them deeper, at least when set against solid stone (figs. 21b, 22), still shallow when isolated (figs. 18–19). This, too, could have been a conscious decision to take the opportunity when it offered itself and sink the joining surfaces further in, so as to give added protection to their fixing – and to the dowel and its fixing – though there would be no sense in setting them very far in, or the function of the dowel would have been impaired.

The picture is completed by some sizable additions in Roman work, such as the back of the head in figure 23,

FIG. 17

Cuirassed statue, right arm below shoulder. Squatly rectangular dowel. Late first century A.D. Bologna, Museo Civico, atrio. Photo: author.

FIG. 18

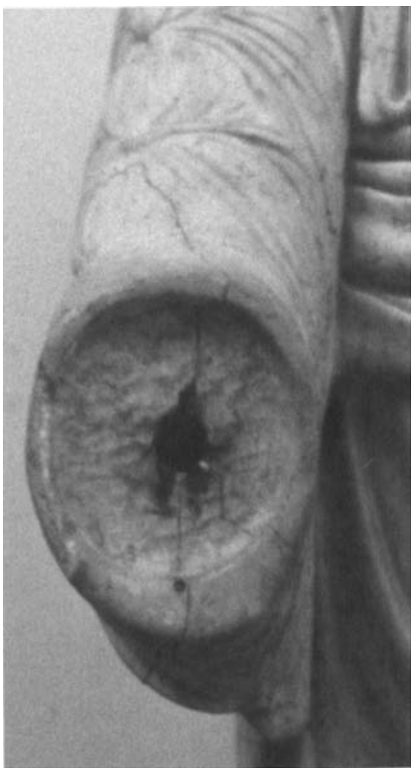
Female statue of kore type, right forearm. Small square dowel. First century A.D., signed by Eleusinios of Athens. Olympia, New Museum L 141. Photo: author.

FIG. 19

Female statue of kore type, right forearm. Round dowel. First century A.D., signed by Eros of Athens. Olympia, New Museum L 140. Photo: author.

FIG. 20

Statue of "Livia" from Velleia, left hand. Square dowel with swelling flange. First century A.D. Parma, Museo Nazionale di Antichità 831. Photo: author.



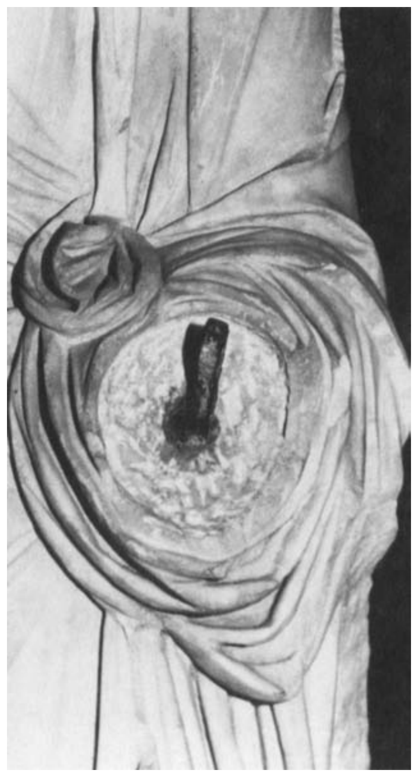


FIG. 21a

Velate statue of Augustus, right forearm. Shallow socket with round dowel. Early first century A.D. Corinth, Museum 1116. Photos: author.

FIG. 21b

Velate Augustus, figure 21a, left hand. Recessed socket with round dowel.

where a plane butting at an almost vertical angle was held in place by glue alone.[71]

In sum, by the second century A.D. there was nothing in the ordinary run of joining that was necessarily beyond the capabilities of available techniques to achieve in a simple fashion. A master of the art could have used marble or metal with equal facility, aided and abetted by highly effective adhesives for both situations. But by the second century A.D., mastery of the art was less and less in demand. The ordinary run of marble statuary was increasingly monolithic. Sculptors like the one in North Africa who made such an odd "marble" join for a lowered arm and such a clumsy "metal" join for a raised arm, or the one at Miletos who made an Archaic type of join for a hand, may have had to devise their own solutions in an aspect of their trade they had never learned – recapturing a forgotten skill. In the hands of other sculptors, however, joining moved into a higher gear. It may have been a largely passive operation for most of its history, responding to pressures beyond the sculptor's control, but it was far from passive in its potential by the time its everyday usefulness came to an end. The apparatus could be turned into what is, in effect, an independent artistic medium.

A fragmentary statue discovered at Philadelphia-Amman in 1947 (fig. 24)[72] provides a particularly striking demonstration. Identified as an anguished Daidalos with the corpse of Ikaros,[73] both the marble and the sculptor were probably Asiatic;[74] the work dates from around A.D. 200. The figure of Daidalos was divided

FIG. 22

"Agrippina" (fig. 10), left hand. Recessed socket with small square dowel. Photo: author.

FIG. 23

Female portrait head. Undoweled butt join for the attachment of a piece to the back of the head. The joining surface is sharply keyed in the center for an adhesive cement. About A.D. 160. Thessalonike, Archaeological Museum 1054. Drawing by author.

into five main pieces – one comprising the head and upper torso as far as the waist, two the arms, and two the lower torso and legs – all butt joins, cunningly contrived to coincide respectively with the belt, the straps of the wing-harness, and the folds of his short mantle. He rose on his right leg, without further support and apparently without a plinth, an impossibility as a monolith and equally impossible in pieces were it not for a long iron rod that was inserted in the core of the leg from foot to upper thigh.[75] The hole for the rod was made with a tubular drill 5 cm in diameter, in itself an operation difficult to imagine in practice, though possibly easier to carry out before the profile of the leg was definitively carved. His left leg, poised in mid-air, would have defeated any attempt to isolate it in a single block. It must weigh in the region of 130–150 kg, defying gravity to such a degree that no marble, however resilient and patiently worked, could stand the strain without assistance. No adhesive could stand the strain either, so a large iron dowel placed horizontally in the center of the join to relieve the weight was supplemented by a long clamp across the top. The upper torso sat solidly on the divided structure beneath, hiding the clamp and keyed in position by a vertical dowel, and constituted a massive nucleus for the attachment of the arms. The right arm, defying gravity again in a gesture that appears to have mirrored

FIG. 24

Statue of Daidalos and Ikaros, from Philadelphia-Amman. About A.D. 200. Amman, Museum J922 (from Iliffe, in *Studies presented to D. M. Robinson*, vol. 1, pl. 78).

that of the left leg but weighing proportionately less, had a square dowel set in the more vertical of the faces of its V-shaped butting. This reinforced the shoulder and acted as a lever in relation to the lower face of the join, the downward pressure of the arm serving to wedge the two elements ever more tightly together. The left arm, raised straight upwards from the shoulder, must have supported the body of Ikaros in the hand. Of Ikaros only a foot, an arm and part of the torso were found – on a scale about half that of the main figure. The torso was hollowed out to reduce the weight, but Daidalos's arm will have been extremely top-heavy nonetheless – a more slender version of his right leg. A second rod was inserted, presumably from the palm right down the length of the arm. It is not clear from the publication whether the rod went through the join at the shoulder as well but it seems likely. The result was an articulated marble statue, conceived on principles quite alien to modern eyes. The rods, unique for their size and purpose, but perhaps not totally without parallel in their own day,[76] take us into a realm where our conventional distinctions between metal and stone no longer apply.

APPENDIX: ANCIENT ADHESIVES

Lime-beeswax-lead oxide. Two samples from works excavated in the Athenian Agora were analyzed in the 1950s.[77] One, taken from the core of a bronze head attributed to the fifth century B.C., was found to be composed of calcium oxide, carbon dioxide, calcium carbonate, and organic matter compatible with beeswax. Laboratory experiments demonstrated that the mixture had good adhesive properties as long as it was not reheated, and one suggestion was that it derived from the fixing of the inlaid eyes. (If so, then one may note the epitaph of M. Rapilius Serapio in Rome [*CIL* VI, 9403], who later made a good living putting such eyes back again!) More relevant in the present context is the second sample, definitely of an adhesive for marble, from a small Hekateion of the first or second century A.D.[78] It, too, was composed predominately of lime (carbon dioxide 31.64 percent, calcium oxide 39.26 percent) and beeswax (17.32 percent) but had also a relatively high proportion of lead oxide (9.32 percent), together with traces of silica (1.83 percent), iron oxide, and alumina (0.63 percent). The silica, iron, and alumina could be impurities in the lime or some brick dust(?);[79] the lead oxide was presumably intentional and must have altered the properties in some way. The purpose to which the adhesive was put was not a very demanding one: it served to fix the statuette into its base.

Lime resin. Resin is mentioned by Pliny (*NH*, XXXIII.94) as a solder for lead and marble. In connection with lead, it may have been used as a flux; in the case of marble, it was surely an adhesive.

Mixtures of resin and lime have been identified on ancient Egyptian stone artifacts[80] and were the basis of some quite powerful adhesives used by restorers of marble sculpture in seventeenth-century Italy.[81]

Lime casein. A lime-casein cement, with good chances of being ancient, was identified on one of the horizontal joins on the Laokoon in the Vatican.[82] Quicklime or gypsum and casein (obtained from skimmed-milk cheese) were the constituents of very strong adhesives for marble made in the seventeenth century and still employed almost down to the present day.[83] The mixture is insoluble in water and thus well suited to outdoor conditions.

From seventeenth-, eighteenth-, and nineteenth-century practice we know that a wide variety of other substances, easily within the scope of ancient technology, could have been used to make adhesives for marble, such as mastic,[84] or proper gelatine glues,[85] but the beeswax-lead oxide cement from Athens illustrates that the ancient world may have discovered further alternatives that have no direct equivalents in the more recent past.

British School at Rome

Notes

Adam:
S. Adam, *The Technique of Greek Sculpture in the Archaic and Classical Periods. BSA* Supplementary vol. 3 (Oxford, 1966).

Dohrn:
T. Dohrn, "Die Marmor Standbilder des Daochos-Weihgeschenks in Delphi," *AntP* 8 (1968), pp. 33–51.

Inan and Alföldi-Rosenbaum:
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G. Mendel, *Catalogue des sculptures grecques, romaines et byzantines*, 3 vols. (Constantinople, 1912–1914).

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C. Michalowski, *Les portraits héllénistiques et romains*. Vol. 13 of *Délos* (Paris, 1932).

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G. Treu, *Die Bildwerke aus Stein und Thon*. Vol. 3 of *Olympia* (Berlin, 1897).

Waywell:
G. Waywell, *Freestanding Sculptures of the Mausoleum at Halicarnassus: A Catalogue* (London, 1978).

1 See A. Claridge, "Roman Statuary and the Supply of Statuary Marble," in J. C. Fant, ed., *Ancient Marble Quarrying and Trade*. BAR International Series, no. 453 (Oxford, 1988), pp. 139–152, passim.

2 Cf. Pausanias' description (VIII.3–6) of the Despoina and Demeter group at Lykosura, much as its monolithic mystique was unmerited (see G. Dickins and K. Kourouniotis, "Damophon of Messene II," *BSA* 13 [1906], pp. 357–404, esp. pp. 384–389). Also Pliny (*NH* XXXVI.37) apropos the Laokoon, though if the Vatican version is what he was referring to, it was actually carved in seven pieces (F. Magi, "Il ripristino del Laocoonte," *MemPontAccad* 11 [1960], pp. 13–22).

3 H. Lechat, *Au Musée de l'Acropole d'Athènes*. Annales de l'Université de Lyon, n.s. 2, Droit, Lettres, fasc. 10 (Lyons, 1903), pp. 227–242. G. Dickins, *Archaic Sculpture*, Vol. 1 of *Catalogue of the Acropolis Museum* (Cambridge, 1912), pp. 37–38, provided a useful typological guide to the joins in his catalogue entries, though these sometimes conflict with the descriptions given in the later catalogue edited by Schrader. Adam, pp. 80–82, extended Dickins's typology to the fourth century B.C. and added some observations on fixing.

Fourth-century practice was commented on briefly by B. Ashmole, "Demeter from Cnidus," *JHS* 71 (1951), pp. 19f., and again by Waywell, pp. 63–64. Also, A. F. Stewart, *Skopas of Paros* (Park Ridge, N.J., 1977), p. 44.

Interest fades in the later Hellenistic period: DarSag, s.v. "sculptura," pp. 1143f. took account of works from Delos, but otherwise P. C. Bol, *Die Skulpturen des Schiffsfund von Antikythera. AthMitt*, Beiheft 2 (Berlin, 1972), pp. 94–96, is the principal exception. And Roman techniques are still uncharted territory, sometimes conscientiously described by early cataloguers (exemplary was Mendel), rarely emulated since.

4 Cf. Akr. 598, 600, 604, 615, 661 (Schrader, nos. 40, 52, 35, 56, 98). To judge from the descriptions in Schrader the butting surfaces are respectively slightly convex and concave rather than strictly planar.

5 P. Cavvadias, *ArchEph*, 1886, p. 76, recorded that traces of cement in a join on Akropolis 673 proved to be ordinary lime, not gypsum, but gypsum may also have been used: Adam, p. 82.

6 Akr. 626. Schrader, no. 26.

7 Akr. 674. The join is broken at the top of the tenon, which is still in its socket and appears never to have been dismantled. Lechat (note 3), pp. 229 and 280, thought the marble plugs that cap the holes represented marble pins; Dickins (note 3) thought they concealed metal pins (p. 38) or channels for pouring lead (p. 213), though cement is what appears around the tenon at the top; Schrader, no. 44, thought the holes were for pouring cement or inserting iron pins.

8 Akr. 594, Schrader, no. 54. Cf. also Akr. 614 (Schrader, no. 27); Akr. 676 (Schrader, no. 49); Akr. 682 (Schrader, no. 41, Adam, pl. 36a); Akr. 686 (Schrader, no. 37). The right arm of Akr. 671 (Schrader, no. 14) appears unusual in having a straight tenon.

9 Akr. 615, Schrader, no. 56. Both arms were attached in the same way. The small scale (half life-size) may have encouraged the sculptor to try the technique as an alternative to a cross-pin (see notes 10 and 11), but there is a large-scale version on a kore from Delos (*BCH* 13 [1889], p. 217, pl. 7).

10 Akr. 600, Schrader, no. 52. Cf. also Akr. 670 (Schrader, no. 8); Akr. 685 (Schrader, no. 47); Akr. 671 – lowered left hand (Schrader, no. 14); and an isolated arm (Schrader, no. 194).

11 Akr. 673, Schrader, no. 51, Adam, p. 48 and pl. 21b; Akr. 679, left arm (Schrader, no. 4). Of course, the higher placement of the outer end of the pin may simply have been an effort to render the hole less visible, or to assist in introducing lead around the pin (see note 13).

12 Akr. 599, Schrader, no. 307. Life-size. The socket is 5.5 cm square and 8 cm deep. The pin-hole is 0.7 cm in diameter. The line of the join probably coincided with the sleeve of the corslet.

13 Lechat (note 3), p. 226, thought the pins themselves were of lead. They may rather have been of iron set in lead (see notes 16 and 21), or iron in cement (note 17), or bronze in cement. The size of the holes is almost standard at 1 cm in diameter, whatever the substance of the pin and its fixing.

14 Akr. 643, Schrader, no. 96. The marble of the upper element is a different quality from the head, but this does not necessarily imply a repair.

15 Akr. 687, Schrader, no. 19.

16 E.g., Akr. 680, Schrader, no. 45, which has an iron cross-pin set in lead at the back and another, not set in lead, inserted at an angle from above, on the front.

17 E.g., a repair to a vertical fold of drapery on Akr. 672, Schrader, no. 42, Adam, pl. 21c, was pierced by three large iron pins, set in cement, their holes 1.2 cm in diameter, larger than the single pin that held the forearm in place. It is interesting that it did not occur to the sculptors to place the pins *inside* the join.

18 Schrader, no. 41, figs 55–57. Akr. 678 and 680 (Schrader, nos. 10 and 45) were probably joined in a similar fashion, but only the upper block of each survives, much damaged about the relevant area.

19 Schrader, fig. 56. No overall measurements are given. G is 5.7 × 2.0 cm.

20 Especially since two were required. Imprint G could result from the implement used to press the lead into the bottom of the socket, or from the dowel, irregularly sawn at its lower end. Wooden dowels, often sheathed in lead, are certainly attested in architecture: R. Martin, *Matériaux et techniques*. Vol. 1 of *Manuel d'architecture grecque* (Paris, 1965), pp. 240–245, 280f. Their use has been proposed in architectural sculpture, attaching pedimental figures to the background or anchoring them to geison blocks: e.g., D. Ohly, *Die Ostgiebelgruppe*. Vol. 1 of *Die Aegineten* (Munich, 1976), p. 112 and fig. 83. For other possible examples in freestanding sculpture, see notes 21 and 22.

21 For instance, if C is a pour-hole or vent-hole, it implies that the join was closed when the lead was introduced, and if so, there should be another hole above, or a channel in the flat surface of the upper or the lower block. Schrader, fig. 55, shows a suitable hole through the back of the upper block, associated with the other socket to the left, but he does not mention it in his text. It could be a subsequent interpolation by the restorers. But rather than a pour-hole, it might have held a cross-pin, pinning the upper end of the dowel in the same way as A pinned the lower end: cf. E. Harrison, *Archaic and Archaistic Sculpture*. Vol. 11 of *Agora* (Princeton, 1965), no. 87, the upper half of a statuette, which has a large socket for a (wooden?) dowel in its underside and a connecting transverse hole from the back, containing a hollow cylinder of lead, interpreted as the setting for an iron cross-pin.

22 Akr. 651, Schrader, no. 107. Half life-size. The butting surface is only 1 cm broad. The common sense of this seems to have struck Milesian sculptors rather earlier: cf. C. Blümel, *Die archaisch griechischen Skulpturen der Staalichen Museen zu Berlin* (Berlin, 1963), nos. 49 and 50, figs. 135–140, which have almost solid socket-and-tenon joins with a narrow lip round the edges. Another late Archaic sculptor in Athens tried a butt join at the base of the neck on a bearded male head, probably for a herm, inserting a large vertical dowel instead: Harrison (note 21), no. 156 with fig. The head is life-size, and the socket for the dowel (which has left no trace) appears so disproportionately large (4.5 cm square by 5 cm deep) that it may have been of wood. A drill hole (1 cm diameter) into the upper end through the back of the neck was presumably for introducing lead.

23 Akr. 688, Schrader, no. 21.

24 Akr. 685, Schrader, no. 47, fig. 47.

25 Waywell, p. 64 and nos. 26, 52, and 55. Cf. a socket for a rounded tenon at Tegea: Stewart (note 3), pl. 6b, no. 8. A truncated cone may reflect nothing more significant than the lower limit of the block used for the head. The Mausoleum statuary was a huge commission.

26 Ashmole (note 3), pls. 4b, 9b. Also, two heads from Athens and one from Eretria: C. Blümel, *Die klassisch griechischen Skulpturen der staatlichen Museen zu Berlin* (Berlin, 1966), pp. 96f., nos. 114–115 (K10–11) and p. 22, no. 12 (K43). The long hair on the head of the so-called Maussollos (Waywell, p. 97, no. 26, pls. 14–15) was undercut so as to butt at the shoulders, with possible repercussions (see note 31).

27 Waywell, no. 85, pl. 27.

28 Many of the Mausoleum heads were probably bedded in lead, though only on the so-called Maussollos is it still in situ: Waywell, p. 98, n. 1. The Demeter from Knidos used only cement. Perhaps the location of the statue was a determining factor. High on the walls of the socket for the (missing) head of Sisyphos I at Delphi are two drill holes, one at the front, the other at the back: Dohrn, p. 39, n. 16, suggested that they may have served for lead, citing the Dionysos from the Trasyllos monument in the British Museum (=B. Ashmole, "The Poise of the Blacas Head," *BSA* 46 [1951], pp. 19f., n. 40). Adam, p. 101, thought they were for cross-pins.

29 On "Maussollos" both tenon and socket survive, and a hole through the back wall of the socket lines up with one in the tenon: Waywell, p. 99. Adam, p. 80, pl. 26a, has another example, on Piraeus 213, which lacks the head but has an iron pin set in lead preserved near the top of the socket wall, hence presumably her interpretation of the holes on Sisyphos I (see note 28).

30 Waywell, nos. 26 ("Maussollos"), 31, 46 (a square dowel hole is visible in pl. 21, but is not mentioned in the text), and 47. On "Maussollos" a channel in the underside of the tenon helped lead (see note 25) to penetrate around both ends of the dowel.

31 E.g., the colossal head of "Maussollos" (Waywell, no. 26) must have weighed about 200 kg in its complete state, which should have been stable enough. But by undercutting the hair so that it rested on the shoulders instead of forming part of the tenon, the sculptors ran the risk that the whole weight would become suspended on those narrow outer walls of stone in the event that the fixing sank. That they were not happy about the quality of the fixing is suggested by the cross-pin (see note 29).

32 Out of eight heads with tenons or fragments of tenons from the Mausoleum, six are flat on the underside (Waywell, nos. 26, 31, 46, 47, 52, 54), and four of those have dowels (see note 30). The two that do not are life-size; on the other hand one of those that does (no. 46) is also life-size, but it has a strong turn in the neck.

33 For an early example, see Ashmole (note 28), pp. 2–6; for Roman examples, see Claridge (note 1), pp. 146f., nn. 21–22.

34 C. Saletti, *Il ciclo statuario della Basilica di Velleia* (Milan, 1968), no. 2, pl. 5; also nos. 5 and 10.

35 Cf. E. Harrison, *Portrait Sculpture*. Vol. 1 of *Agora* (Princeton, 1953), p. 5, and nos. 1 (Antonine), 17 (Flavian), 23 (Hadrianic), 51 (third century), 52 (third/fourth century), as opposed to 10 and 11, both Julio-Claudian; but no. 24 (Hadrianic) is also very shallow. G. Traversari, *Statue iconiche femminili cirenaiche* (Rome, 1960), p. 92, proposed a typology based on the shape and depth of sockets ("heart," hemispherical, truncated cone, "sugar lump," etc.) and argued that it had a chronological value among his twenty-seven examples. But the only consistent trend – and there are exceptions there too – is that the sockets tend to get deeper with time. Common sense dictates caution in attempting to impose a rigid classification; still less is it likely to prove a reliable aid in dating.

36 E.g., Mendel, vol. 2, nos. 556, 599; Inan and Alföldi-Rosenbaum, nos. 16, 22; V. Poulsen, *Les portraits romains*, vol. 1 (Copenhagen, 1962), nos. 30, 89.

37 Cf. also Poulsen (note 36), no. 56; idem, *Les portraits romains*, vol. 2 (Copenhagen, 1974), no. 52 (which included a bit of the neckline as well); Saletti (note 34), no. 12, pl. 42.2. Some workshops may have made a habit of it: e.g., R. Bol, "Das Statuenprogramm des Herodes-Atticus-Nymphaeums" *OlForsch* 15 (1984), no. 28, pl. 15; no. 34, pl. 29; and Treu, p. 259, pl. 64. 4–5. The Augustus from Prima Porta has a V-shaped extension that slots into a matching cutting in the back wall of the socket (not illustrated in any published source).

38 E.g., R. Calza, *I Ritratti*, part 1. Vol. 5 of *Scavi di Ostia* (Rome, 1964), no. 32, pl. 19; Mendel, vol. 2, no. 559. Two of the portrait heads from Delos (Michalowski, nos. 10 and 15) had dowels, whereas four did not (ibid., nos. 5, 6, 13, 16), including some with extremely shallow tenons (here fig. 11c). Dowels are similarly rare among Traversari's range of shallow sockets from Cyrene (see note 35): no. 13, with a substantial square dowel; no. 28, with only a small circular pin.

39 Traversari (note 35), no. 13 has a pour-channel cut into the back wall of the socket, connecting with the dowel hole. Cf. also Mendel, vol. 2, no. 628, another statue from Cyrene, with a dowel and traces of lead in what sounds like an extremely complicated technique involving eleven cuttings in the socket walls.

40 A female head from the Hadrianic Baths at Aphrodisias preserves the end of an iron pin in a hole at the back of the deep but slightly undercut tenon: Inan and Alföldi-Rosenbaum, no. 182, pl. 135. Cf. also Mendel, vol. 3, no. 1109, an imperial cuirassed statue from Tralles. The head of a gray marble horse in the garden of the Bursa Museum at Carthage (unpublished?) was added with a reduced socket-and-tenon join, now broken across the tenon to reveal a cement setting with an iron cross-pin (in lead).

41 Inan and Alföldi-Rosenbaum, no. 168, pl. 127, cf. also no. 69, pl. 61; Poulsen, vol. 2 (note 37), no. 192, pl. 313; R. Calza, *I Ritratti*, Part 2. Vol 5 of *Scavi di Ostia* (Rome, 1977), no. 85. Straight butt joins, with dowels, above the neckline, simply suggest replacement: A. Claridge, "A Late Roman Portrait Head," in H. Hurst and S. Roskams, eds., *Excavations at Carthage: The British Mission*, vol. 1, part 1 (Sheffield, 1984), pp. 213f.

42 Waywell, no. 104.

43 K. Stemmer, *Untersuchungen zur Typologie, Chronologie und Ikonographie der*

Panzerstatuen. ArchForsch 4 (1978), p. 127 and index s.v. "Stückungstechnik" – unterhalb Panzerrand. For a semi-draped heroic nude, see the Augustus from Thessalonike: *AA*, 1940, p. 262, fig. 72, where the tenon is just visible.

44 Stemmer (note 43), V 17; also VII 12 (=J. Paul Getty Museum 71.AA.436).

45 Waywell, no. 34, p. 111.

46 The socket measures 4.5 × 12 cm and is 15 cm deep. Incidentally, although the dowel hole is wider at the bottom than at the top, the dowel is unlikely to have been similarly wedge-shaped (pace Waywell, p. 63) since it would then be impossible to slot into the socket. The hole might have served first for a lewis in lifting the statue onto the building, the upper part of the rider being added once it was in situ; otherwise, the wedge-shape of the hole could be just an error in carving.

47 A. Pasquier, *La Vénus de Milo et les Aphrodites du Louvre* (Paris, 1985), pp. 30f. Cf. F. Ravaisson, *La Vénus de Milo* (Paris, 1871), p. 6.

48 Dickins and Kourouniotis (note 2), p. 387. Only the front view is illustrated (fig. 9, on p. 368), but the join is probably like that for part of Anytos's himation (p. 382, fig. 22). Comparable is a piece of drapery on the Hermes at Olympia (Treu, p. 202, fig. 232).

49 N. de Chaisemartin, *Les sculptures romaines de Sousse et des sites environnants. CSIR* Tunisie-Proconsulaire, vol. 2, part 2 (Byzacium) (Rome, 1987), pp. 18f., no. 7 with pls., including two detailed photographs of the join, one with a surviving fragment of the tenon replaced. De Chaisemartin (p. 19) suggests that the technique is perhaps due to the attribute once held in the hand, which was either very heavy or, together with the arm, was meant to be substituted on occasion. Extra weight, however, is the last thing we might expect to be entrusted to a marble tenon; as for taking off the arm every now and then, I don't know, but it is more probable that the method is simply a homemade version of the Lykosura type, taking the chance to avoid a dowel, but without a strong adhesive.

50 The stump of one is preserved, diameter 1.3 cm. The associated joining surface is battered but appears to have been "stepped" in some way, perhaps to assist fixing.

51 Treu, p. 74, no. 2, fig. 119; cf. also p. 92, no. 4, fig. 159, and pp. 76 f. "Theseus," fig. 120.

52 Agora S 37: *Hesperia* 2 (1933), p. 175; Adam, pl. 15c.

53 Mendel, vol. 1, no. 126. Cf. also ibid., vol. 3, no. 1109, with a deep socket-and-tenon for the left hand (the same statue used a cross-pin in attaching the head: above, note 40). A huge socket, possibly for a marble tenon, was prepared at the join for the whole of the raised arm on a cuirassed statue at Ostia: Calza (note 38), no. 180.

54 Ashmole (note 3), p. 19, pl. 9a. The iron dowel for the left arm is partly preserved, set in what looks like cement; that for the right arm is represented only by rust stains. In cross-section the holes measure 0.7–0.8 × 2.2–2.4 cm (1:3). On the Mausoleum statuary only rust – no dowels – survives but Waywell, nos. 26 (right arm), 70, 77, 97, 98, 101, 104, all have reasonably complete dowel-holes, their heights variously 3, 5, or or even 7 times their widths. One may note also that the large dowel that probably performed a more than keying role for the upper half of the rider (see note 46) was strongly rectangular. Cf. also dowel holes on Aknonios, Daochos I, and Sisyphos I at Delphi: Dohrn, pp. 37–39, figs 6–8, pls. 30, 32, though Dohrn (p. 51) would see the right arms of Aknonios and Daochos I as repairs post 107 B.C.

55 E.g., Waywell, nos. 63(?), 68, 77, 78. (It is highly doubtful, pace Waywell, p. 64, that the holes on the edge of the drapery of no. 96 and on the edge of the join on no. 101 constitute double dowels.) To judge by a group of four drill-holes just above the rectangular dowel on the left arm, the sculptor of the Demeter from Knidos may have thought of using a squarer dowel and then changed his mind (Ashmole [note 3], p. 19 suggested they were the remains of a pour-hole for lead, but I cannot see how that could be). The dowels on the Demeter are unusual in being orientated at about 45° within the joins, perhaps to counter torsion.

56 On Waywell, nos. 68 and 78 the supplementary dowels are round, 1.1–1.5 cm in diameter and not very deep. They may have been keying pins instead (compare Waywell, no. 87, pl. 27, which had four pins helping to attach a piece of drapery, and no. 193, fig. 20, where two pins keyed the front part of a foot). That is, they were not intended to support a great weight but served to assist the adhesive.

57 E.g., a 1:4.5 dowel supported the right arm of a colossal Herakles from the Antikythera wreck (Bol [note 3], p. 53, no. 24; the other instance he cites, pp. 94f., n. 193, is actually round: cf. p. 55). For some later Roman examples: Inan and Alföldi-Rosenbaum, no. 3, pl. 4.1 (right arm), and Stemmer (note 43), VII 21, pl. 60.1.

58 E.g., British Museum 1480, left hand and right forearm (0.6 × 1.9 cm); also Mendel, vol. 1, no. 134; and R. Bol (note 37), no. 32, pl. 25; no. 33 (right forearm). Ashmole's hope (note 3, p. 19) that the shape "might prove a useful criterion of date and even of workshop" was obviously not unfounded but equally obviously has to be invoked with caution.

59 Arms at shoulder: square – Harrison (note 35), no. 56, pls. 36f.; round – Mendel, vol. 2, no. 585; Stemmer (note 43), VIII 5, pl. 70.1. Cf. also F. Winter, *Die Skulpturen.* Vol. 7, part 2 of *Altertümer von Pergamon* (Berlin, 1908), no. 211, which used round dowels for both arms, both feet and the head; and the statues from Silahtarağa (see note 76).

60 E.g., the statue from Sousse (see notes 49 and 50). Two dowels were used to support the right forearm on a colossal seated Zeus from Gaza (Mendel, vol. 2, no. 611), but since there is also a clamp across the outside of the join, indicating a repair, one of the dowels may be a later substitute. Two small counter-pins accompany a square dowel at the shoulder of a cuirassed statue from Rome(?): Stemmer (note 43), I 10a, pl. 7.1.

61 There are pour-holes associated with the other doweled joins noted above (see note 51).

62 E.g., the tail of a horse from the Mausoleum: Waywell, no. 2, p. 88, pl. 6. It is very likely that, if a hole was made to introduce lead around the body end of a dowel, as on the Athena from Eretria (Adam, p. 81 and pl. 35c), where the lead survives, then both ends of the dowel were set in lead, otherwise there would be no need for the hole.

63 E.g., the right arm of Daochos I at Delphi: Dohrn, p. 38, figs. 8–9, which has lead at the body end but no sign of a pour-hole or vent (though admittedly the join is very fragmentary).

64 E.g., the right arm of Sisyphos I, which has been reattached, has no pour-holes in the arm or the body: Dohrn, p. 39, pl. 32a. The body ends of Demeter's forearm dowels were apparently set in cement (see notes 54 and 55), though it is possible that the arm ends were fixed in lead while they were still separate.

65 Waywell, p. 63 and nos. 26 (right arm), 70, 77, 100. The evidence consists of a drill-hole running at right angles from outside the join into or at least toward the inner (upper) end of the dowel hole. On nos. 77 and 100 the drill-holes contain traces of a dark reddish-brown metallic-looking substance, which is probably iron. It would be residual, of course, deriving from the main dowel, or it might not be iron. There is a strong possibility of confusion with holes for pouring or venting lead. Aknonios at Delphi (Dohrn, p. 37, figs. 6, 7) has *two* drill-holes at similar angles associated with the dowels for each arm, which Dohrn interpreted simply in terms of lead since the lower of the two holes on the right preserves a (solid?) core of lead. It is possible, nonetheless, that the upper ones in both cases were for cross-pins. A comparable pair of holes on the lowered (repaired?) right arm of an Asklepios at Eleusis (Adam, p. 104) should be noted, though it is no more conclusive. Adam states with confidence that they were for double cross-pins but cites the right arm of "Daochos" (she presumably meant Aknonios) as her only parallel.

66 E.g., lead at both ends is probable in the case of a join on one of the Antikythera statues, which has a vertical pour-channel cut in the joining surface: Bol (note 3), p. 55, no. 37, pl. 29.1. Lead at the body end is attested on many Roman works where the arm is at right angles or higher (e.g., here figs. 21, 21b), presumably poured in before the join was closed, using cement for the other end. The right arm of the cuirassed statue in Malibu (see note 44) had its dowel set in lead, now removed.

67 E.g., on the right arm, lowered from the shoulder, of a late Hellenistic statue from Thasos (Mendel, vol. 1, no. 130), and on the right forearm of an Augustan statue from Magnesia ad Sipylum (ibid., vol. 2, no. 591). There is a possible instance from Pergamon in the second century B.C.: Winter (note 59), vol. 7, part 1, p. 113, no. 87. Only lead is mentioned in the text, but the illustration seems to show a hole or the stump of a pin in the opposite side of the dowel hole, in line with the transverse drill-hole and its traces of lead. British Museum 1751, one of the cuirassed equestrian statues from Lanuvium, datable about 75–50 B.C. (F. Coarelli, "Il santuario tardo-repubblicano di Lanuvio," *Archeologia e Società. Rivista bimestrale del Centro Regionale "Lanuvium"* 2 [1976], pp. 62–70), has an enormous socket for the lowered right arm and a drill-hole that penetrates to the opposite side of the socket, but perhaps the dowel was of wood, or the join was actually a butting socket-and-tenon of Archaic type, with a cross-pin in the Archaic manner.

68 On a statue from the Baths of Faustina at Miletos (Mendel, vol. 1, no. 117) the upper end of a rectangular iron dowel for the lowered right arm survives, set in lead, and there is a hole above the join, which could connect with the upper end of the dowel hole. Mendel saw its contents as an iron pin and did not hazard a guess at its function. When I saw the statue in 1984, I thought it was a pour-hole to introduce lead down the full length of the dowel. The case is complicated by the fact that on the outside of the join is one end of a deep-set cutting for a C-clamp, a feature one would normally associate only with repairs, but which might represent an alternative to cross-pins at both ends of the dowel. The use of lead, however, is clear, and some sort of additional fixing was employed as well, either in a primary or secondary situation. That lead was used at all might be a specific measure against the humid conditions of a bath building (it may be noted that the same group of statuary included a hand [see note 53] that avoided a dowel altogether).

69 Cf. Waywell, no. 63, pl. 25, and nos. 68, 77, 78, 98, 101, 107, for claw work; no. 97 is lightly pointed (see also Stewart [note 3], p. 44). Comparable is what remains of the joining surface for the left arm of Aknonios at Delphi, which Dohrn, p. 37, accepts as original.

70 Cf. Waywell, no. 26, pl. 13; no. 68, pl. 26; no. 104, pl. 28. Partial sockets were sometimes formed when making the join under a fold of drapery, e.g., idem, no. 63, pl. 25.

71 Alternative practice in such situations included butting socket-and-tenon joins (e.g., Inan and Alföldi-Rosenbaum, no. 342, pl. 250; Calza [note 41], no. 13) as well as straight butt joins with a variety of pins and larger dowels.

72 J. Iliffe, "A Heroic Statue from Philadelphia-Amman," in G. Mylonas, ed., *Studies Presented to D. M. Robinson*, vol. 1 (St. Louis, 1951), pp. 705–712, pls. 75–80. Original height to top of head about 1.90 m (head 27 cm).

73 H. Möbius, "Ein hellenistischer Daidalos," *JdI* 68 (1953), pp. 98–101. There are two holes in the back of the shoulders, which Iliffe (note 72) thought may have served to attach the figure to a wall, but which Möbius preferred as sockets for the attachment of wings.

74 Iliffe (note 72), p. 708, describes the marble as coarse-crystaled white with bluish gray tones and suggests, p. 711, an Aphrodisian connection, on the grounds of workmanship and style. D. Brinkerhoff, *A Collection of Sculpture in Classical and Early Christian Antioch* (New York, 1970), p. 45, quoted the statue as an example of long-distance trade from Prokonnesos, shipped in pieces for assembly at its destination. While there is no compelling reason to believe that particular hypothesis, links with Asia Minor are strengthened by an inscription from the Gymnasium at Ephesos, recording another sculptural group on the theme of Daidalos and Ikaros, set up in the Trajanic period: Möbius (note 73), p. 101.

75 The stone at the top end of the rod would have been much thicker when the drapery was still intact. Iliffe (note 72), p. 706, observes that although there were traces of iron at the bottom end of the hole, the hole itself was clean. He proposed that the rod had been encased in or wedged with wood.

76 Compare the circular iron dowels, set in "cement," which joined sections of limbs on a group of statuettes found near Istanbul: N. de Chaisemartin and E. Orgen, *Les Documents sculptés de Silahtarağa*. Editions Recherche sur les Civilisations, Institut français des Etudes Anatoliennes, Memoire no. 46 (Paris, 1984), pp. 81–83, esp. fragment no. 123. A date in the third quarter of the second century A.D. is argued (p. 88), and Aphrodisias is again (cf. note 74) proposed as a likely source (pp. 90f.), the technique explained as facilitating transport.

77 M. Farnsworth and I. Simmons, "A Unique Cement from Athens," *Hesperia* 29 (196), pp. 118–122.

78 Found in a late well with debris probably deriving from the Herulian sack of A.D. 267: Harrison (note 21), no. 147.

79 The seventeenth-century diary of Nicholas Stone, Jr. (W. L. Spiers, *Walpole Society* 7 [1918–19], p. 196) reports, apropos making adhesives in general, that the "fine dust of brickes . . . is held more usefull than the dust of marble by reason of itts lightnesse mixese better."

80 A. Lucas, *Ancient Egyptian Materials and Industries*, 3rd ed. (London, 1948), pp. 12–13.

81 P. Dent Weil, "Contributions toward a History of Sculpture Techniques: I. Orfeo Boselli on the Restoration of Antique Sculpture," *Studies in Conservation* 12.3 (1967), pp. 90 and 98, n. 19. Forty-eight parts of pure rosin and one of beeswax were melted and mixed together, lime (marble dust) was gradually added until the mixture ran thinly and would break cleanly when tested by dropping some on a cold marble slab and leaving it to cool. To use it, both parts of the join had to be heated, as hot as possible.

82 Magi (note 2), pp. 9 and 16. All definitely post-antique restoration work used *mistura forte* (see note 85).

83 Cf. the recipe given by Nicholas Stone (Spiers [note 79], p. 196, also quoted in full by Weil [note 81], p. 98, n. 19), which is practically the same as one given in the 1910 *Encyclopedia Britannica* s.v. "cement." It was warmed for use.

84 Nicholas Stone (Spiers [note 79], p. 196; Weil [note 81], p. 98, n. 19): rosin, wax, a little turpentine, and mastic. Mastic was extracted from *pistacia lentiscus* and well known in the ancient Mediterranean, the best coming from Chios (Dioskurides, *De materia medica*, I. 50–51).

85 Cf. D. Diderot and J. L. d'Alembert, *Enciclopédie ou Dictionnaire raisonée des sciences, des arts et des métiers*, vol. 3 (Paris, 1753), s.v. "colle," p. 627; "colle à pierre" (marble dust, mixed with resin) and "colle-forte." Lengthy instructions for preparing "colle-forte" (the Italian *mistura forte*) by variously boiling and straining animal skin, cartilage and tendons, etc., are given in the *Supplément*, vol. 2 (1756), s.v. "colle-forte," pp. 503–504.

Repair, Reuse, and Reworking of Ancient Greek Sculpture

Evelyn B. Harrison

Repair, reuse, reworking. I was invited to talk about these aspects of ancient Greek sculpture not because I am any sort of expert on them but rather, I imagine, because the excavations of the Athenian Agora, where I have worked for a long time, have so many examples of them. So I shall just show a selection of these and try to touch on some broader questions connected with them. For the discussion of reworking, I regret very much that we do not have someone here to speak on reworking of ancient sculpture in more recent times. Perhaps Seymour Howard and Carlos Picon, who have studied the work of master restorers such as Cavaceppi,[1] will be willing to join in the discussion afterward.

From the very beginning of our exploration it will be apparent that we cannot say anything at all independently of the questions of style and the dating based on style that we give to these objects. The fact that they come from a regular excavation and that the circumstances of their finding have been recorded does virtually rule out the possibility that they are postantique, but generally that is all. We shall come across one or two that were found in well-dated contexts early enough to help us with their dates, but this is unusual for sculpture in a city excavation, where broken marbles become building stone and are used over and over for successive generations of houses, walls, and even cesspools.

For examples of repair we might start with a class of sculpture that was typical of the Agora and is represented there by examples ranging from Late Archaic through Roman times. They are the herms, depicted on a pelike by the Pan Painter around 470 B.C. (fig. 1).[2] These curious images of the god Hermes consist of a human head on top of a rectangular post with square projections at the sides like chopped-off arms of a scarecrow, and a phallos lower down on the front of the shaft, erect in the earliest examples, more modest in later ones. Both the face and the phallos are protective, scaring off not just crows but ghosts and bad luck of all kinds. We know from ancient writers that the herms stood in front of doorways, both of sanctuaries and of private houses. City gates also had their herms, and at the northwest corner of the Agora, outside the place where the Archaic city gate had once stood,

FIG. 1

Pelike by the Pan Painter. Side A: three herms. Paris, Musée du Louvre C 10793 3.
Photo: Chuzeville.

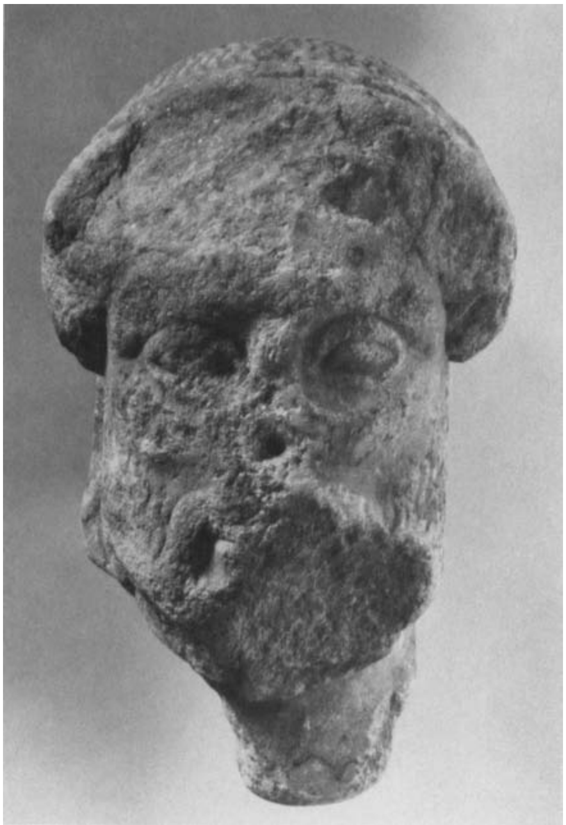


FIG. 2

Head of a herm, about 480–470 B.C. Athens, Agora Museum S 211. Photo: American School of Classical Studies at Athens, Agora Excavations.

FIG. 3

Head of a herm found in a late fifth-century B.C. deposit. Athens, Agora Museum S 2452. Photo: American School of Classical Studies at Athens, Agora Excavations.

dedications of herms were made in such numbers that the area was commonly called "the Herms." The Pan Painter's conversational group of three may have been inspired by three herms that we know were set up in this place by three generals, to celebrate their victory in the battle of Eion in Thrace in 476 B.C.[3]

Sometimes the herms themselves had bad luck. We know of one famous occasion in 415 B.C. when a group of young men deliberately chopped the faces off almost all the herms in Athens, both public and private, thus arousing fears of an impending coup that might deliver Athens over to her enemies.[4] But, considering the exposed position of the herms, they must also have been accident prone in the ordinary course of everyday life. If one of them was knocked over by, say, a heavily loaded cart backing into it, it might very well fall on its face and require a new nose.

Our earliest example is a battered head (fig. 2) that was found in a modern house torn down in the early years of the Agora excavations.[5] The nose has been broken and repaired. The broken surface was smoothed off and the new surface picked so that it would hold cement. In addition a hole was drilled and a pin put in to hold the new nose more firmly. Since there is no rust stain in the hole, it may be that the pin was bronze. The head is made of Parian marble with a rather coarse grain, the kind generally used in Archaic sculpture, and the carving of the eyes, with very heavy lids, seems to belong to the Early

FIG. 4a

Repair piece for a herm. Right side. Athens, Agora Museum S 159. Photo: American School of Classical Studies at Athens, Agora Excavations.

FIG. 4b

Front of repair piece for herm, figure 4a.

Classical Style. Also, the long hair is braided and the braids tied around the head, a fashion that comes in only at the end of the Archaic period.

There is a huge temptation to connect this head with some historic event. Because it was certainly made before 415 B.C., the first thought is that it was damaged in the infamous Mutilation in that year. Because its style would fit the 470s, it could be one of the three herms set up by the three generals after Eion. But suppose we are dating it a few years too late; it could have been damaged by the Persians in 480. In that case, however, it would have been less likely to be repaired. Finally, it seems that the area outside of the northwest corner of the Agora suffered heavy damage when the Roman general Sulla sacked Athens in 86 B.C. Pausanias, writing his guidebook in the second century A.D., passed through this area without mentioning the Herms, but when he came to the Gymnasium of Ptolemy, somewhere east of the Agora, he remarked that there were some interesting herms there.[6] Maybe these came from the historic Stoa of the Herms where the Eion herms had stood. After the destruction of the Stoa they might have been rehabilitated and given a new home in a kind of herm museum in the gymnasium.

Another patched herm head from the Agora (fig. 3) has a better-dated context.[7] Broken off from its shaft, it was deposited in a small enclosed votive pit inside the northwest corner of the Agora that was sealed off around the end of the fifth century B.C. Its style suggests that it was carved not long after the middle of the century. The face is in excellent condition except for a square-cut patch in the lower

FIG. 5

Foot with drapery, made separately for attachment to a pedimental figure of the so-called Theseum. Athens, Agora Museum S 737. Photo: American School of Classical Studies at Athens, Agora Excavations.

lip. Though the dates of the head and of its deposit would indicate that it was aboveground in 415, it does not look like a mutilated herm, for its eyebrows and nose show no signs of a smashing blow. This patch seems carefully made to replace a lower lip that was defective, either because of a flaw in the marble or because of a mistake in the carving. It has been shaped so that the joint, which looks so prominent now, would not have cut through the bare flesh anywhere but would follow the line of parting of the lips and the edges of the mustache and beard around the mouth. The joint, filled with white cement, would have been concealed by the color on the lips and the beard. But since no color survives on the piece, in spite of its fresh condition and its short lifetime aboveground, I am inclined to think that the care lavished on this repair was wasted and that the herm was never actually painted and set up in public but lay around unused until the time when a head of Hermes was needed for inclusion in this mysterious sanctuary of an earth-related divinity.

Finally we have a strange piece (figs. 4a–b) that seems to be a patch for a herm that was heavily damaged but considered worth keeping, perhaps a herm with a history or one from a group of such herms that had suffered more than its fellows.[8] Here the extent of the damage made it impossible to avoid cutting through bare flesh; the joint surface slices through the cheeks well above the outline of the beard. The workmanship is sketchy and the finish scratchy and blurred. It is hard to tell whether the damaged original was Late Archaic or archaistic. The back and top of the head may have been in one piece and the upper face in another. The broad cutting must have served for a

FIG. 6a

Upper part of a horse's head. Right side. Roman imitation of Parthenon style. Perhaps a repair piece for the west pediment of the Parthenon. Rome, Museo Gregoriano Etrusco 1016 (from Brommer, *Die Skulpturen der Parthenon-Giebel*, pl. 94.1).

metal dowel to attach this piece to the top of the head. The small round hole may have served to attach the upper face, either by means of a pin that passed through a hole in this dowel or just by lead that was poured in and became a pin.

In architectural sculpture we sometimes find added pieces of which it is hard to be sure whether they are later repairs or pieces added separately at the time when the sculptures were placed on the buildings. The forepart of a foot in Parian marble (fig. 5) has a low, carefully cut plinth such as we find on pedimental sculptures of the fifth century B.C.[9] Since it was found in a medieval cistern deposit just north of the so-called Theseum, it seems natural to think that it comes from that temple. The toes are undercut so that they do not rest on the pediment floor. On top they are heavily weathered, suggesting that they were near the front edge of the cornice. We could think, then, that the undercut toes projected beyond the shelf on which the sculptures rested. At the back of the piece is a sloping joint surface rough-worked for cement but with no sign of a dowel hole. Folds of drapery are carved on the plinth beside the foot. So we imagine that this foot emerged from under the drapery of the figure to which it belonged. We can picture the statue, without this projecting foot, being set close to the edge of the cornice shelf but not quite up to the edge. Then this piece could have been pushed in like a wedge from the front. Cement, together with the weight of the statue above, would have been enough to hold the piece in place with no need for a metal dowel.

To judge from the many dowel holes in the pediment floors, the figures of the Theseum pediments were close-set

FIG. 6b

Left side of horse's head, figure 6a (from Brommer, pl. 95.1).

with some overlapping, some figures being placed far forward on the cornice and others close back against the tympanon.[10] Those set near the front edge must have needed to be handled very carefully, and a projecting foot would have made a difficult job even more so. Thus the piecing may have been intended from the beginning. The Parian marble of the foot is of a slightly coarser grain than the other fragments we have that may belong to the Theseum pediments, but the forms and carving of the toes are similar to those of another foot in the finer marble, and the execution of the fine drapery folds looks like authentic fifth-century work.

The west pediment of the Parthenon has a similarly dense composition with overlapping figures. The group of Kekrops and his daughter, recently taken down from the pediment and moved into the Akropolis Museum, was set close to the front edge of the cornice. The fragment of a coiled snake belonging to the group, which is in the British Museum, has recently been discussed by Brian Cook, who believes that it is a Roman repair rather than an originally attached piece. He very generously lent me the text of his article in advance of its publication. The piece is analogous to our foot in that it projected beyond the edge of the pediment floor, as we see from the weathered line on the bottom. Also, it was not attached by a dowel but simply shoved under the figures. Although the snake fragment had previously been taken as original, when the group came down to the Akropolis Museum, it was possible to see that the joint surface to which the snake was applied contains a rectangular mortise, but there is no corresponding tenon on the snake piece. Therefore Cook concluded that this is not the original addition. He argued that the tenon of the original was secured by means of an iron pin, which rusted in time and caused the tenon to split off. Thereupon, the damaged joint surface was cut back to the smooth surface that we see now. The fact that the repair piece did not quite fit the statues and had to be trimmed down in places to allow it to be pushed under them seems to confirm the idea that this is a repair.

Cook suggests that the repair was done in the second century A.D., when we have other indications that scaffolding must have been set up on the west pediment of the Parthenon. The smooth, relatively featureless and carefully finished snake body, however, does not show any characteristics that are specifically Roman.[11]

The situation is different with the upper part of a horse's head in the Vatican (figs. 6a–b). This is of about the right scale as well as the right style for a horse from the west pediment, and its pose and pattern of weathering indicated to Hermine Speier that it belonged to the outer horse of Athena's chariot.[12] The workmanship, however, appears to be Roman. It shows poorly smoothed chisel work on the face in front and running-drill channels in the mane in back. It is sawn off flat below and hollowed out underneath, as if to reduce its weight. The answer may be that this is a repair piece made in the second century A.D. to mend some damage that befell the upper part of this horse's head.

A repair to a large sculptural complex can involve making whole new figures. Here the new work does not show up as patching or recutting but is distinguished from the original pieces by a different style of carving overall. Well-known examples are the corner figures from the west pediment of the Temple of Zeus at Olympia that were made after an earthquake in the fourth century B.C. They are carved out of a different marble and the surface finish and the structure of the faces are different, but from the distance at which they were viewed, these differences would scarcely have been apparent.[13]

The colossal group of statues in the Temple of Despoina at Lykosoura in Arkadia was seen by Pausanias in the second century A.D. He names the sculptor, Damophon of Messene, but he does not say when Damophon lived.[14] After long debate, a date sometime in the second century B.C. has become generally accepted. But about twenty years ago, Edmond Lévy carried out an excavation inside the temple in which he found Hadrianic coins below the level of the statue base.[15] He concluded that the whole group and Damophon himself must belong to the time of Hadrian. This was applauded by Guy Donnay, who took the occasion to stress the superiority of archaeological and historical method to the study of style, which had been proven wrong in this case.[16] Not all of the students of sculpture took that lying down, however. Several scholars, among them Giorgos Despinis and Jiří Frel,[17] pointed out that one had only to look at the figures of Tritons that adorned the throne.

FIG. 7a

Unfinished decorative herm recut from a Roman portrait herm. Left side. Athens, Agora Museum S 363. Photos: American School of Classical Studies at Athens, Agora Excavations.

FIG. 7b

Back of unfinished herm, figure 7a.

FIG. 8

Fifth-century grave stele reused in the Roman period as monument of Agathokles. From Thespiai. Athens, National Museum 742. Photo: Hirmer Fotoarchiv München.

FIG. 9

Late fifth-century grave stele reused in the Roman period as monument of Aphrodisia. From Thespiai. Thebes Museum, BE 21 (from Demakopoulou and Konsola, *Archaeological Museum of Thebes*, pl. 7).

FIG. 10

Late fifth-century grave stele reused in the Roman period as monument of Diodora. From Thespiai. Athens, National Museum 818 (from Diepolder, *Die Attischen Grabreliefs*, pl. 8.1).

These are on display in the Athens National Museum. The Tritoness who supported one of the arms has the round face and eyes and the strongly plastic carving of the major sculptures that belong to the group.[18] The other one is obviously Roman with its flat, slick surfaces and harshly etched details. This must be a replacement made during a repair in Roman times.[19] Shortly after the appearance of Lévy's article, Jean Marcadé went with him to Lykosoura where they made a careful investigation of all the fragments of sculpture belonging to the group that were in the museum there. They found many joins: among others, they joined to a foot of one of Damophon's goddesses a toe found by Lévy in a lower stratum, which he had taken to be earlier than the construction of the base for the group. In their joint article Lévy recants his earlier conclusion, recognizing with Marcadé that the activity in Hadrian's time consisted in repairs, not in a new creation.[20]

We come now to reuse. I shall not take much time with the simplest and crudest form of reuse, that is, taking a piece of sculpture with no regard for what it represents but only as a piece of marble out of which you can make something else. If the original piece is big enough not to hamper the shaping of the smaller new piece and if the latter is completely finished, we have no way of knowing what has happened. Undoubtedly there was a lot more of this going on in antiquity than we realize. It is the unsuccessful pieces and those abandoned half-finished that come to our attention, and they are a depressing lot. Here a portrait herm of the Roman period, as we can recognize from the nicely carved locks of hair surviving on either side

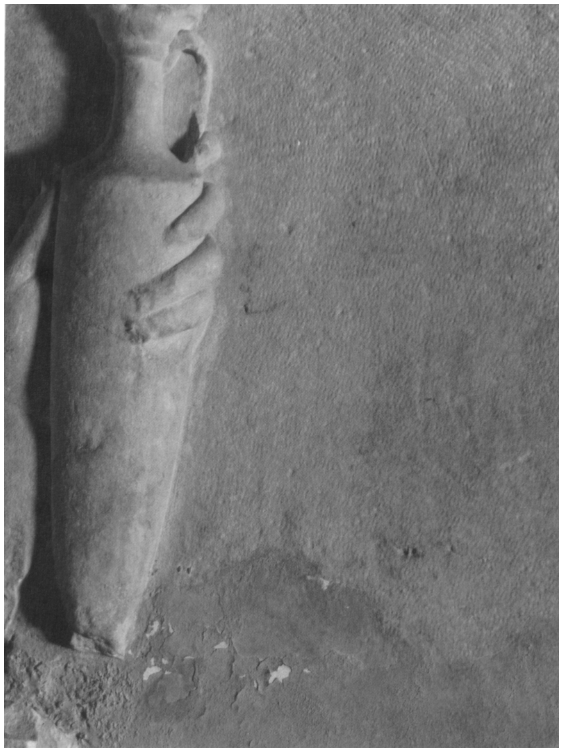


FIG. 11a

Grave stele of a woman reused in the Roman period. Probably from Thespiai. New York, The Metropolitan Museum of Art, Rogers Fund, 1908, 08.258.42. Photos: The Metropolitan Museum of Art.

FIG. 11b

Detail of grave stele, figure 11a, showing background reworked with tooth chisel.

(fig. 7a), was in the process of being carved into a smaller herm, probably intended for some decorative use. It has been cut off flat on the back (fig. 7b) and a kind of shelf cut into the back of the head as if to support something. This piece is from the Agora, but we don't put it in the front window.[21]

More attractive is what would be called in today's jargon "adaptive reuse": taking a damaged and/or neglected monument and rehabilitating it for a use similar to its original one but with certain necessary changes. An interesting series of examples comes from Thespiai in Boeotia. Here in the Roman period the Thespians reused gravestones of their ancestors from the later fifth and fourth centuries B.C. to mark the graves of their own dead.[22] A fifth-century relief in the Athens National Museum (fig. 8) showing a now unidentified boy with his dog has had its crown reworked and inscribed in big letters of Roman date "Agathokle Chaire," Farewell Agathokles.[23] The surface of the relief was partly reworked with a toothed chisel, probably to remove stains in preparation for repainting. So the boy's leg, which would not have been colored and would have shown even light stains, exhibits chisel-marks, while the adjacent drapery, which could have been sufficiently freshened up by paint, was left smooth. This reverses the usual patterns of finishing. The lower right corner may have been more heavily patinated. The whole figure of the dog as well as the background have been chiseled over.

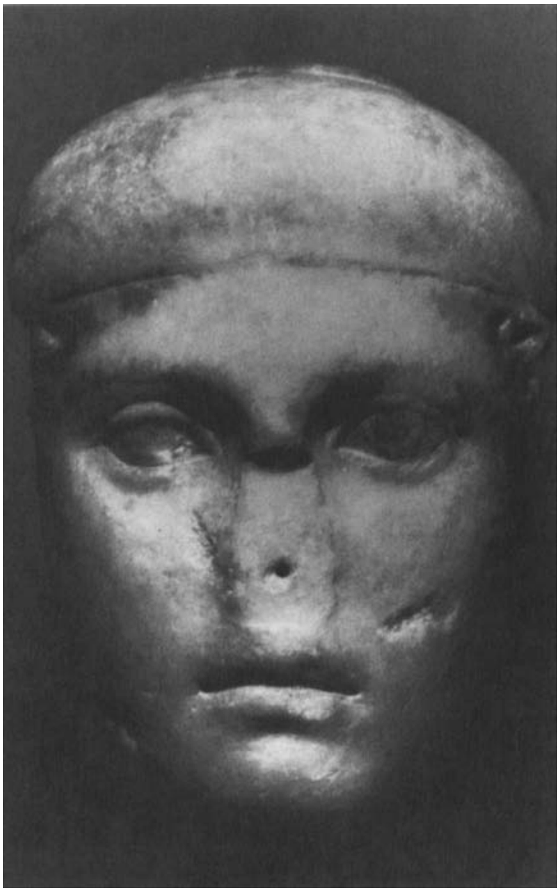
The majority of the gravestones of this group are now in the Thebes Museum. Some of the figures have had their broken noses mended with metal pins, like the herm with which we began this survey. That is the case with the stele of Aphrodisia (fig. 9), whose name has been carved on the background after the original inscription was erased. A veil that she held up with her right hand has been chiseled away.[24]

On a stele from Thespiai in the Athens National Museum (fig. 10) a more drastic intervention has taken place.[25] The woman's name, Diodora, has been carved on the epistyle in letters that are unobtrusive though unmistakably of Roman style, but the figure of a little boy who originally stood in front of the seated woman has been chiseled away, together with a bird that she was holding out to him. Evidently Diodora had no son. This makes us wonder whether these gravestones belonged identifiably to the families of those who reused them, for one would not want to erase a long-gone member of one's own clan. Perhaps these were more like the ready-made ancestors that some people buy today from auction houses.

We see that the figure of a woman seated on a klismos is popular among these Thespian grave reliefs. A stele in the Metropolitan Museum of Art in New York (fig. 11a) was said to come from Attica, but for a long time scholars have been noticing that it does not really seem to be Attic.[26] The simplified treatment of its pediment, the stiffness of the pose and of the folds of the drapery, and above all the tooth-chisel marks all over the background (fig. 11b), except in the lower part where extremely heavy weathering has erased them, betray its secret. The marble, too, looks like that of the Thespian stelai. Two big chunks are missing. On one was the head – one wonders if it is hiding in some private collection. The other must have held the missing inscription, carved on the background in front of the figure as on the stele of Aphrodisia in Thebes; it might perhaps be turned up by a diligent search in Boeotian epigraphical storerooms.

"Adaptive reuse" on a larger scale occurs with Greek architecture and architectural sculpture in Roman times. This includes not only the carrying off to Rome of pediments, akroteria, and architectural members from Greece, Sicily, and Magna Grecia but also the moving into Athens of whole buildings or parts of them from damaged buildings elsewhere.

A number of marble sculptures found in Rome have been regarded as transported Greek originals. For example, the Niobids, of which the most famous is the Dying Niobid in the Terme Museum in Rome – others are in Copenhagen – are generally agreed to have been part of a Classical Greek pediment, but no satisfactory suggestion has been made as to what temple they belonged to.[27] Klaus Vierneisel has pointed out the various indications of reworking



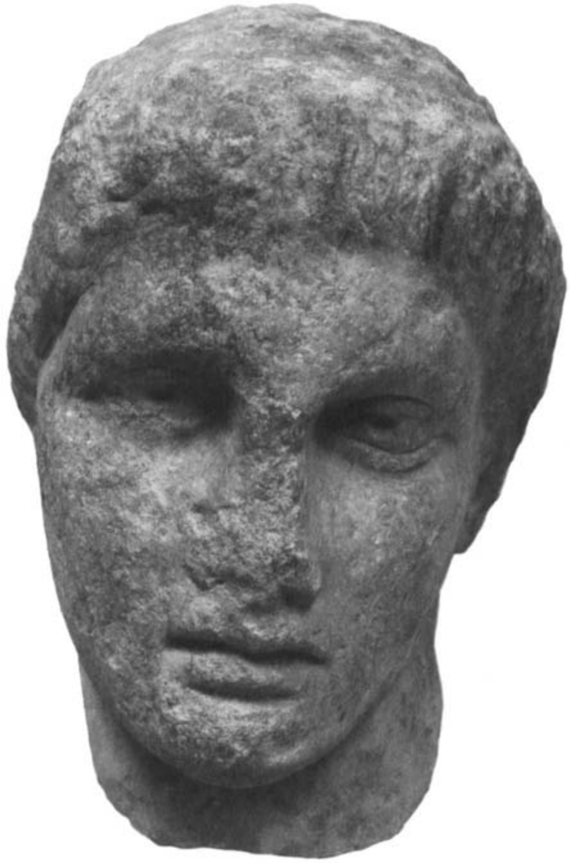


FIG. 12

Head of Nike from Temple of Apollo Sosianus in Rome. Fifth-century original repaired in the time of Augustus. Rome, Musei Capitolini 3456 (from La Rocca, *Amazzonomachia*, pl. VI).

FIG. 13

Head of a youth. Fourth-century B.C. original reworked in the Roman period. Athens, Agora Museum S 212. Photo: American School of Classical Studies at Athens, Agora Excavations.

connected with their second use.[28] These include rubbing down the surfaces to clean them and recutting parts of the plinths, which may have become patinated during their pedimental use.

Eugenio La Rocca has recently assembled a whole group of sculptures belonging to a pediment of the Temple of Apollo Sosianus on the south slopes of the Capitoline, rebuilt around 30–20 B.C. These are Classical Greek works in Parian marble representing the joint expedition of Herakles and Theseus against the Amazons. Taken from a damaged Greek pediment, they have been cleaned by smoothing, like the Niobids, and also repaired. They represent the most complete and most instructive group of reused ancient Greek architectural sculpture known to us so far. These have been excellently published by La Rocca in the catalogue of the exhibition that he mounted in the Palazzo dei Conservatori in 1985.[29] Let us take just one example, the head of a Nike (fig. 12) who may have been crowning Theseus.[30]

The cutting for the repaired nose and the hole for its metal dowel are like those in the early herm from the Agora except that the joint surface is smooth. Such a smooth surface without the dowel appears in a repaired head from the Kerameikos in Athens.[31] In the Nike head a small drill may have been used to clean out the channel

FIG. 14a

Statue of a goddess in wingless flight. Early fourth-century B.C. akroterion. From the Athenian Agora. Athens, National Museum 1732. Photos: American School of Classical Studies at Athens, Agora Excavations.

FIG. 14b

Detail of figure 14a showing rasp marks on right thigh.

between the parted lips (here I am judging only from the photograph). The cleaning of the surface by abrasion has blurred the forms to such an extent that the sculptor has outlined the eyelids and the edge of the kerchief with engraving to reclarify their contours. A similar outlining of the eyelids is seen in the head of a youth in the Athenian Agora (fig. 13), where the pupils of the eyes have also been drilled.[32] It looks as though this head may have come from a fourth-century grave monument; it is uncertain for what it was reused. On the Nike head there are traces of the painting of the eyes. This must be repainting, for the cleaning would have destroyed whatever remained of the original paint.

The Temple of Ares in the Athenian Agora was evidently taken down stone by stone from its unidentified original site, moved, and re-erected with the help of a system of lettering on the blocks that showed exactly where each stone belonged in the building. These letters have made it possible to identify a great many blocks belonging to the temple that have been found reused in many different ways in structures of many different periods. From them we know the essential features of the temple from the lowest steps up through the horizontal cornice, indicating that the reconstructed temple, at least up to this level, was all of one piece, not put together with material from various places.[33] The roof remains a mystery, however.[34] The Temple of Ares was a Doric hexastyle peripteral temple very close in size and architectural

FIG. 15a

Statue of Nike. Early fourth-century B.C. akroterion. Athens, Agora Museum S 312. Photo: American School of Classical Studies at Athens, Agora Excavations.

style to the so-called Theseum. The Theseum was richly adorned with sculptures: metopes, porch friezes, and pediments. The akroteria, too, may have been figural, though we have no proof of this.[35]

It would be natural to think that the Temple of Ares had some or all of these features, but the proof is lacking because only scraps of the upper architecture survive. We have identified no certain pieces of either the raking cornice, which would have framed the pediments, or of the raking sima on which the akroteria would have stood. A fine Pentelic marble statue of a goddess in wingless flight (figs. 14a–b), suitable for a central akroterion, was found in 1891 in a wall of

FIG. 15b

Detail of figure 15a showing Roman recutting with pick on plinth and chisel on support. Photo: author.

the fifth century A.D. that was cut through by the trench for the Athens-Piraeus electric railway and is now in the Athens National Museum.[36] It has been attributed to the Temple of Ares since that is the nearest Classical temple of the right size. A winged Nike (fig. 15a) that was found in front of the Stoa of Zeus in 1933 seems to have been a corner akroterion and might be the right size for the Temple of Ares, though Homer Thompson thought it should belong to the south wing of the Stoa of Zeus, in front of which it was found.[37] By usual proportions it seems too large for the Stoa. Without going into these questions, we can notice that both pieces show signs of recutting of the plinths such as Vierneisel noted in the Terme Niobid. This is most striking on the winged Nike, where the front of the base (fig. 15b) looks freshly cut, with marks of flat and bull-nosed chisels, suggestive of the Roman period, and the front of the plinth rechopped with the point, whereas the back is rough and heavily patinated and seems to show a weathered line marking the level to which the plinth was sunk into its base. It is not impossible that the wings of the Nike were also repaired. The parts close to the body are made of gray marble, whereas the long outer feathers are white. The wingless goddess (fig. 14a) has lost her plinth, but there are marks of a bull-nosed chisel on the front of the curved pier that connected the figure to its base. This figure also shows very heavy rasping in areas of flesh that were overhung by the drapery, as on the right thigh (fig. 14b). Though it is not out of the question that some of this is original, it might also be the result of cleaning off patina that had darkened the flesh area.

It would seem, then, that the idea of attributing

FIG. 16

So-called Aura from the Palatine. Early fourth-century B.C. akroterion. Rome, Museo Nazionale Romano 124697. Detail showing rasp marks on proper right side.
Photo: DAI Rome.

these pieces to a wandering temple such as the Temple of Ares is at least supported by these evidences of reuse. It is striking, however, that we do not have the visible sculptured surfaces smoothed down, as in the Apollo Sosianus figures and the Niobids. This may be partly because the marble is Pentelic rather than Parian and is carved in a way that emphasizes crisp edges whose effect would be destroyed by rubbing down. The so-called Aura from the Palatine in Rome is generally agreed to have been carried off from Greece, and it is strikingly similar to our Athenian Pentelic marble akroteria.[38] It shows some heavy rasping (fig. 16) like that on our wingless goddess, and the surface has not been rubbed down. The plinth is missing.

In all the forms of reuse that we have surveyed

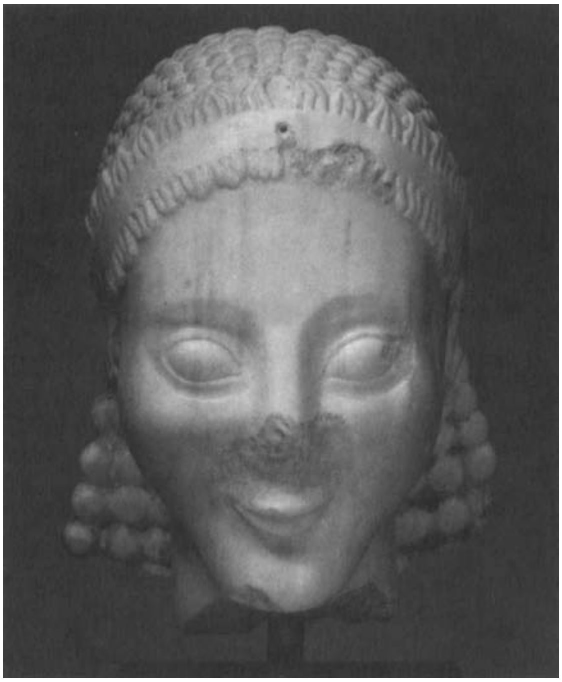


FIG. 17a

Archaic head of a youth with modern recutting. Front. New York, The Metropolitan Museum of Art, Rogers Fund, 1921, 21.88.16. Photos: The Metropolitan Museum of Art.

FIG. 17b

Left side of Archaic head, figure 17a.

so far, except for the simple reuse of the marble to make something altogether unrelated, there has been some serious effort on the part of the restorers to preserve the aesthetic qualities of the object in its new environment. The restorers are neither ignorant of the original meaning of the works nor are they inept craftsmen. In many ways they are the counterparts of the eighteenth-century restorers who prepared ancient marbles to take their place in palatial environments. The principal difference is that the ancient restorers also restored the color, whereas postantique restorers do not. There is thus a more uniform treatment of all surfaces in eighteenth-century restorations than in the antique ones, and no need is felt to sharpen up boundaries that have been blurred by cleaning.

The anciently restored marbles that have come out of the ground have generally lost their color as well as their second noses and are to our eyes uglier than never-restored pieces that are simply broken. Such reworked pieces, even when ugly, have a certain historical interest, provided that their provenance is accurately recorded and sufficiently informative. In excavations and in museums displaying the products of excavations they have a place. In the art market and in museums for which the market is the main source, they represent a real danger, for the idea of an anciently recut original can serve as a mask for the ineptitude of a forger.

Museums of all kinds seem to have a conspiracy of silence about works on public display that have been disfigured by inept recutting of any period, ancient, medieval, or modern. The kouros from Keratea in the Athens National Museum has a face so crudely recut that whoever started the recutting, perhaps in the late Roman period, gave up the attempt and left the job unfinished. Catalogues and labels have described it simply as "unfinished," leaving one to blame the original sculptor for the botched job, and visitors have tended to pass by it without the second glance that would reveal the original high quality of the kouros. This is still so, even after a detailed discussion of the true state of affairs in a 1968 article by the then director of the museum, Vasilios Kallipolitis, and the sculptor Stelios Triandis.[39] The label has not changed.

A head of Athena in the same museum was listed by Panagiotis Kastriotis in his catalogue of 1908 as "helmeted head of Athena, Roman." No one, so far as I know, has ventured to guess when it got its present naive-art nostrils and mouth, but one might suspect the Frankish or the Turkish period. Semni Karouzou in her 1968 catalogue just says that the nose and mouth are "missing."[40] She assigns the head correctly to the mid-fifth century on the basis of the fine carving that we see in the side view, where we are no longer mesmerized by the goblin face. But why not even mention what is the most striking first impression that any visitor gets?

Various technical aids help us to recognize modern recutting of ancient works, but even when this has been done and the results reported to the scholarly community, the general public is too often presumed not to be interested. So an Archaic head of a youth in the Metropolitan Museum of Art in New York (figs. 17a–b) was first condemned as a forgery by Frank Brommer, then vindicated by Dietrich von Bothmer, who examined it under ultraviolet light and saw that all the dubious carving showed up in a different color from the good passages, some of which, like the lower lip, are really beautiful.[41] Why not give everyone the chance to enjoy the good parts of the work by explaining clearly what needs to be overlooked? Altogether, we know so little about the remnants of ancient art in our keeping that it is hardly worthwhile to make a mystery of what we do know.

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Notes

1 S. Howard, *Bartolomeo Cavaceppi* (New York, 1982); *Bartolomeo Cavaceppi: Eighteenth Century Restorations of Ancient Marble Sculpture from English Private Collections*, London, The Clarendon Gallery, 1983 (catalogue by C. A. Picon).

2 Louvre C 107933, *ARV*² 555, no. 92; *Paralipomena*, p. 386; J. de La Genière, "Une Péliké inédite du Peintre de Pan au Musée du Louvre," *REA* 62 (1960), pp. 249–253, pl. 11; E. Harrison, *Archaic and Archaistic Sculpture*. Vol. 11 of *Excavations of the Athenian Agora* (Princeton, 1965), pl. 65a; E. Simon, *Götter der Griechen* (Munich, 1969), p. 308, fig. 295.

3 For discussion of this, see de La Genière (note 2) and Harrison (note 2), pp. 108–117.

4 Thuc. VI.27–28; Andok. I (*De Mysteriis*). For extensive commentary, see D. MacDowell, *Andokides on the Mysteries* (Oxford, 1962).

5 Agora S 211, Harrison (note 2), pp. 142–144, no. 156 (with bibl.), pl. 40; H. A. Thompson and R. E. Wycherley, *The Agora of Athens*. Vol. 14 of *Excavations of the Athenian Agora* (Princeton, 1972), p. 95, pl. 50a; D. Willers, *Zu den Anfängen der archaistische Plastik in Griechenland*. *AthMitt*, Beiheft 4 (Berlin, 1975), pp. 36–38, pls. 20.3, 21.1–2; E. Harrison, *Gnomon* 53 (1981), p. 497.

6 Paus., I.17.2. The Gymnasium of Ptolemy has not been located, but it seems evident from the route of Pausanias that it was somewhere east of the Agora.

7 Agora S 2452, T. L. Shear, Jr., *Hesperia* 42 (1973), pp. 164–165, pl. 35a–b; H. A. Thompson, *Agora Guide*³, p. 236, fig. 40; J. Camp, *Gods and Heroes in the Athenian Agora. Excavations of the Athenian Agora*, Picture Book 19 (Princeton, 1980), p. 12, fig. 22; idem, *The Athenian Agora* (London, 1986), p. 75, fig. 49.

8 Agora S 159, Harrison (note 2), pp. 144–145, no. 158, pl. 41.

9 Agora S 737, W. B. Dinsmoor, *Observations on the Hephaisteion*. Hesperia, Suppl. 5 (Cambridge, Mass., 1941), pp. 118–120, figs. 49–51; H. A. Thompson, *Hesperia* 18 (1949), pp. 234–235, E, pl. 52.4–5; C. Gottlieb, *AJA* 61 (1957), pp. 161, 163; H. A. Thompson, *AJA* 66 (1962), p. 344, n. 22, p. 346, n. 28; A. Delivorrias, *Attische Giebelskulpturen und Akrotere des fünften Jahrhunderts*. Vol. 1 of *Tübinger Studien zur Archäologie und Kunstgeschichte* (Tübingen, 1974), pp. 19, 26, 28, 53, pls. 6a and c.

10 For the most complete and accurate record of the pediment floors, see B. Sauer, *Das sogenannte Theseion und sein plastischer Schmuck* (Leipzig, 1899), pp. 19–23, pl. II. Sauer remarks, p. 20, that it is not possible to distinguish a priori between dowel-holes and attribute-holes. Sauer, who restored excessively large figures, and H. A. Thompson, *Hesperia* 18 (1949), pl. 63, who restored the east pediment with sparsely set figures, used as attribute-holes several cuttings that seem to me more likely to have held dowels fastening the plinths of figures.

11 B. F. Cook, "Parthenon West Pediment B/C: The Serpent-fragment," *Kanon, Festschrift Ernst Berger. AntK*, Beiheft 15 (1988), pp. 4–8.

12 Vatican, Museo Gregoriano Etrusco 1016, H. Speier, in G. Lippold, ed., *Die Skulpturen des Vatikanischen Museums*, vol. 3, part 2 (Berlin, 1956), pp. 522–524, unnumbered, pl. 236; F. Brommer, *Die Skulpturen der Parthenon-Giebel* (Mainz, 1963), p. 98, no. 9, pls. 94–95.

13 B. Ashmole, N. Yalouris, and A. Frantz, *Olympia* (London, 1967), pp. 21–22, pls. 65, 70 (original with restored right arm in Pentelic marble), pls. 62–63 (replacement figure, entirely in Pentelic marble), also p. 179, on the dates of the replacement figures.

14 Paus., VIII.37.3–5. E. Lévy, "Sondages à Lykosoura," *BCH* 91 (1967), pp. 518–545; see pp. 518–522 for a useful summary of previous scholarship on the group.

15 Ibid., pp. 532–538.

16 G. Donnay, "Damophon de Messène et les Phaidyntai d'Olympie," *BCH* 91 (1967), pp. 546–551.

17 J. Frel, "Réparations antiques," *AAA* 5 (1972), pp. 73–82; see p. 73, n. 1. Before Frel's article appeared, G. Despinis pointed out to me in conversation that one of the Tritons is Hadrianic.

18 National Museum 2171, S. Karouzou, *National Archaeological Museum: Collection of Sculpture* (Athens, 1968), p. 173, pl. 58.

19 National Museum 2175, ibid., p. 173: "inferior, cold and unexpressive, may be a replacement of the first century A.D."

20 E. Lévy and J. Marcadé, "Au Musée de Lycosoura," *BCH* 96 (1972), pp. 967–1004. See esp. p. 986:

En revoyant le fragment découvert dans l'un des sondages de 1966 plus bas que les fondations de la base, nous avons constaté qu'il complétait les orteils du pied droit. Les conclusions premières de l'étude stratigraphique sont à réviser en conséquence, et à nuancer: si des travaux importants ont certainement été exécutés à l'époque d'Hadrien, on ne peut plus affirmer qu'ils consistaient dans un remplacement du groupe; de simples réparations paraissent le plus probables.

21 Agora S 363, Harrison (note 2), p. 166, no. 214, pl. 57.

22 Thespian reliefs as a stylistic group were first treated by G. Rodenwaldt, "Thespische Reliefs," *JdI* 28 (1913), pp. 309–339. He notes, p. 332, that reuse is "found repeatedly among the Thespian reliefs." Apart from the examples cited in this paper, the most important ones are in the Thebes Museum. W. Schild-Xenidou, "Boiotische Grab- und Weihreliefs archaischer und klassischer Zeit" (Ph.D. diss., Munich, 1972) includes most of them in her catalogue but without illustration.

23 National Museum 742, Karouzou (note 18), pp. 40–41; Schild-Xenidou (note 22), pp. 14–15, no. 14, with selected bibl.

24 Thebes BE 21, I. Threpsiades, *ArchDelt* 16 (1960), p. 148, pl. 125b; idem, *EphArch*, 1963, Suppl., pp. 11–12, pls. Theta and Iota; Schild-Xenidou (note 22), pp. 24–25, no. 24; K. Demakopoulou and D. Konsola, *Archaeological Museum of Thebes: A Guide* (Athens, 1981), p. 43, pl. 7.

25 National Museum 818, H. Diepolder, *Die Attischen Grabreliefs des 5. und 4. Jh. v. Chr.* (Berlin, 1931), p. 15, pl. 8.1. Karouzou (note 18), p. 107; Schild-Xenidou (note 22), pp. 23–24, no. 23.

26 The Metropolitan Museum of Art 08.258.42. G. M. A. Richter, *Catalogue of Greek Sculptures in the Metropolitan Museum of Art* (Cambridge, Mass., 1954), p. 50, no. 75 (with bibl.), pl. 61. W.-H. Schuchhardt, *Gnomon* 30 (1958), p. 491, compares it to the fragment of a grave relief from Marion in Cyprus in which he sees Ionian characteristics. P. Zanker, "Eine Eigenart ausserattischen Reliefs," *AntK* 9 (1966), p. 18, calls the relief Ionian.

27 Terme Niobid: Museo Nazionale Romano 72274. A. Giuliano, ed., *Museo Nazionale Romano: Le Sculture*, vol. 1, part 1 (Rome, 1979), pp. 176–179 (with bibl.); see p. 179 for the suggestions that have been made about its origin. Copenhagen statues: F. Poulsen, *Catalogue of Ancient Sculpture in the Ny Carlsberg Glyptotek* (Copenhagen, 1951), pp. 267–271, nos. 398 (inv. 520) and 399 (inv. 472). E. La Rocca, *Amazzonomachia: Le sculture frontonali del tempio di Apollo Sosiano* (Rome, 1985), pp. 71–72, discusses the possibility that the Niobids came from the opposite pediment of the same temple as the Amazonomachy reused in the Temple of Apollo Sosianus but were considered unsuitable in subject matter to adorn the Augustan temple and so were placed in a nonpedimental setting in the Gardens of Sallust.

28 K. Vierneisel, "Untersuchungen zu den Niobidenfiguren Rom-Kopenhagen-Berlin" (abstract), in *Greece and Italy in the Classical World.* Acta of the XIth International Congress of Classical Archaeology, London 1978 (London, 1979), p. 223.

29 Most completely presented by La Rocca (note 27). See also idem, "Le Sculture frontonali del tempio di Apollo Sosiano a Roma," in H. Kyrieleis, ed., *Archaische und klassische griechische Plastik*, vol. 2 (Mainz, 1986), pp. 51–58.

30 La Rocca (above, note 27), pp. 26–27, II b, pls. 4–6, p. 28, fig. 8a, third and fourth color plates (unnumbered).

31 Kerameikos P 313, H. Riemann, *Kerameikos*, vol. 2 (Berlin, 1940), pp. 87–88, no. 116, pl. 26; J. Frel, *AAA* 5 (1972), p. 74, no. 3, figs. 3–4; Delivorrias (note 9), pp. 164–166, pls. 56b–d and 57.

32 Agora S 212, T. L. Shear, *Hesperia* 2 (1933), pp. 528–531, figs. 13–14.

33 W. B. Dinsmoor, "The Temple of Ares at Athens," *Hesperia* 9 (1940), pp. 1–52. For further study of the temple, see M. H. McAllister, "The Temple of Ares at Athens: A Review of the Evidence," *Hesperia* 28 (1959), pp. 1–64.

34 Dinsmoor (note 33), pp. 32–37, assigned to the Temple of Ares some sima blocks, including an akroterion base, which he believed would not fit on the Theseum. W. B. Dinsmoor, Jr., has shown, however, that these pieces do belong to the Theseum. See W. B. Dinsmoor, Jr., "The Roof of the Hephaisteion," *AJA* 80 (1976), pp. 223–246 (pp. 232–240 on the simas).

35 The single corner sima block with akroterion base assigned to the temple (see note 34) has a very regular circular cutting that might more likely have served to attach a floral akroterion than a figure.

36 National Museum 1732, P. N. Boulter, *Hesperia* 22 (1953), pp. 141–147, pls. 47–48; Karouzou (note 18), p. 41, pl. 22; Delivorrias (note 9), pp. 122–123, pls. 39–40.

37 T. L. Shear, *Hesperia* 4 (1935), pp. 374–375; H. A. Thompson, *Hesperia* 6 (1937), p. 37; E. Harrison, *AJA* 65 (1961), p. 190; Delivorrias (note 9), pp. 137–142 and see index, pls. 43c–d, 44–45; B. S. Ridgway, *Fifth Century Styles in Greek Sculpture* (Princeton, 1981), pp. 62, 212, 228, fig. 37.

38 Museo Nazionale Romano 124697, Giuliano (note 27), pp. 204–206, no. 127, with bibl. (J. Papadopoulos).

39 National Museum 1904, Karouzou (note 18), p. 26: "crude work of a local marble worker;" G. M. A. Richter, *Kouroi*, 3rd ed. (London, 1970), p. 98, no. 89 (with bibl.), figs. 291–292: "unfinished." V. Kallipolitis and S. Triandis, "A Propos du Kouros de Kératéa," *AAA* 1 (1968), pp. 280–285.

40 National Museum 1763, Karouzou (note 18), p. 40.

41 The Metropolitan Museum of Art 21.88.16, F. Brommer, "Falsche Köpfe," *AA*, 1963, pp. 439–450. Reply by D. von Bothmer, "The Head of an Archaic Greek Kouros," *AA*, 1964, pp. 615–627. Brommer's short riposte, "Auge oder Lampe," *AA*, 1965, pp. 552–553, points out that there is no mention of reworking in G. M. A. Richter's 1954 *Catalogue of Greek Sculptures*, no. 2. He thus leads us to the conclusion that his article suggesting that it was a forgery served the useful purpose of driving the museum to examine its work more closely and report on the results.

Metal Attachments in Greek Marble Sculpture

Brunilde S. Ridgway

The ancient Greeks seem to have had a strong appreciation for fine marble; it is therefore remarkable that they chose occasionally to mix media and add metal attachments to a stone sculpture – all the more so since other contemporary cultures appear to have resisted the practice, or to have used it only in highly selective and specific instances. I shall attempt here to summarize the various forms in which the Greeks employed metal on marble, which I have grouped into four categories: *functional*, *realistic*, *practical*, and *bizarre*. For each of these I shall mention only a few examples, but I shall try to suggest earliest occurrences, possible prototypes or foreign parallels, diffusion, and length of practice. Although some forms of this tradition continue into Roman times, I shall end my survey with the Hellenistic period; it should also be stated at the outset that the peak of this practice occurred during the Archaic phase, circa 650–480 B.C. Subsequent centuries saw the predominance of bronze statuary in the round, to which a different kind of mixed-media technique was applied (a form of *Metalmalerei*), so that most of our later marble examples fall within the sphere of relief and architectural sculpture. In addition, many Classical and Hellenistic works are known today only through copies and therefore provide no safe evidence for our purposes. I shall end with a problem: a form of metal attachment that should fall within the functional category, but which has remained unclear and deserves further study.[1]

In the *functional category* I include those uses of metal that perform a service function, and in which the bronze, iron, or lead employed are not meant to be especially noticeable.These are primarily the clamps and dowels that fasten separately carved pieces to a greater whole, or firm a statue on its base. The typical example is to be found within the Akropolis korai that make an offering gesture with forearm outstretched (for instance, Akropolis 673 or 679). The lower portion of the arm was carved from a separate piece of marble, and one end of it, fashioned as a tenon, was inserted into a socket obtained within the upper arm, at the bend of the elbow, where the joint could be hidden by drapery (see fig. 12). To make the added piece secure, a metal lock-pin was inserted diagonally, piercing through both socket and tenon, or rather fitting into a hole drilled across the arm. The breaking of the outstretched limb has often occurred at that weakened point, thus exposing the drilled channel and the portion of the forearm tenon still remaining in the elbow socket. Comparable uses of metal can be found in securing a plinth to a base: A bronze or iron dowel may attach the two, but more often the space between the statuary plinth and the cavity made in the base to receive it was simply sealed with molten lead, as in the case of the funerary statue of Phrasikleia.[2]

This form of metal use is obviously derived from architectural practices: Fastening devices in wood, bronze, and iron, sometimes sealed in lead, are known from many ancient areas, and are in Greece attested from the early sixth century on, clamps apparently occurring relatively earlier than dowels. What is remarkable is the fact that our earliest sculptural example – the separately carved penis of a belted stone kouros on Delos, traditionally dated to the late seventh century or the early sixth – may precede known architectural evidence. A hole was drilled amid the curls of the pubic hair, connecting with the channel carved between the testicles to receive the penis, and the space was then filled with molten lead, which acted as a glue. Since the pouring hole, once filled, appeared as a dark spot on the marble surface, as visible also today, one assumes that the pubic curls were painted in such a way as to hide the intrusion. Later examples of separately carved genitals were put in place with less elaborate means, often simply with marble cement; but the early date of the Delian kouros – among the first examples of Greek monumental marble sculpture – suggests that its sculptor was uncertain of the strengths and limitations of his medium and preferred to play safe by overbracing the joint. On the other hand, metal pins attaching separately carved marble parts or attributes continued to be used throughout Greek sculpture, as attested, for instance, by a Hellenistic (second-century?) gravestone from a cemetery near the Pergamene Asklepieion, where the left arm of a seated man was joined at mid-biceps and along the thigh, probably holding some object.[3]

My *realistic category* includes all those cases in which the object added in metal would have been in metal in "real life" – for instance, most types of jewelry and weapons. The Akropolis korai again provide numerous examples: One still retains a metal bracelet (Akropolis 670), others have several holes drilled in their necks for added necklaces, on their diadems for applied ornaments, in their earlobes for metal earrings. The metal additions are especially surprising in this last case, since both diadems and disc earrings were easily rendered in stone and easily decorated with paint. In the Peplos Kore (Akropolis 679), thirty-five attachment holes in two rows encircle the head; they range between fifteen and twenty-five mm in depth, and some

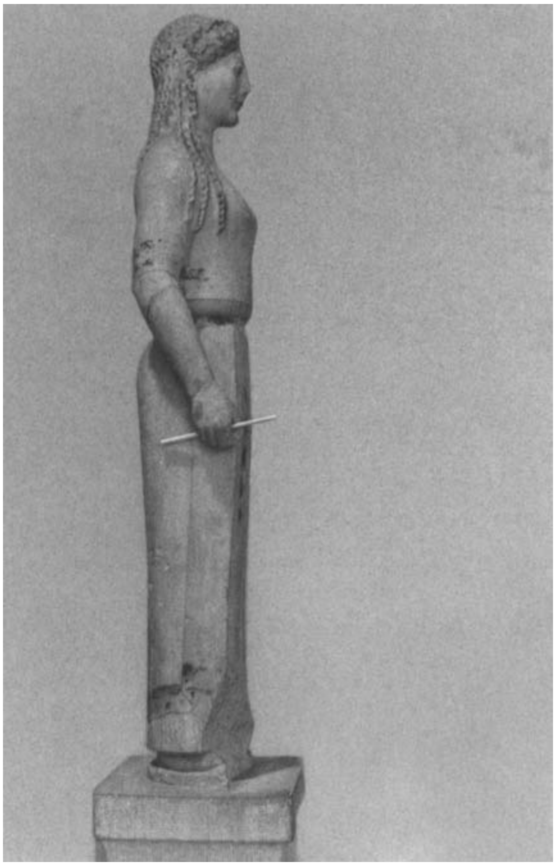

FIG. 1a

The Peplos Kore. The modern rod in the right hand was probably a metal weapon in antiquity. Athens, Akropolis Museum 679. Photos: DAI Athens.

FIG. 1b

Detail of the Peplos Kore, figure 1a.

preserve lead pins approximately four mm thick (figs. 1a–b). This elaborate head ornament has not been properly explained, and we shall return to this point.[4]

This form of metal additions may have been inspired by the practice of putting real clothing, and perhaps real jewelry, on wooden statues, such as the Athena Polias in Athens, or the Brauronian Artemis. Examples of votive gifts on sacred statues can be found in modern churches in Italy and Greece today, but this is different from the conception and creation of a sculpture endowed with metal ornaments from the start. In Egypt and the Near East, jewelry in precious metals can be found on statuary in bronze or other rare media, but – to my knowledge – not on stone works.[5] The Peplos Kore, dating from approximately 540–530 B.C., is among the earliest Attic freestanding figures so richly adorned, but by that time the use of metal additions to marble statuary was well established, and sculpture from the Cyclades provides earlier examples.

In considering the range of this applied decoration, we may note that not only freestanding sculpture but also architectural pieces were thus embellished. The so-called ex-Knidian Karyatid in Delphi (circa 540–530 B.C.) has minute holes drilled through her diadem, and even on her disc earrings, perhaps for the attachment of pendants. From the fifth century, the remarkable head of

FIG. 2

Nike of Paros. Detail. Paros Museum 303. Photo: DAI Athens.

Hera, once on the East Pediment of the Parthenon, exhibits on her hair three rows of attachment holes with different diameters, the smallest alternating on either side of a narrow fillet rendered in marble. The practice was also known outside the Greek mainland, on the islands, as shown by the so-called Archermos' Nike from Delos (circa 550), and it continued at least as late as the Severe period, as shown by the Nike of Paros (circa 470 B.C.), whose marble peplos was "fastened" by separately added metal pins at the shoulders (fig. 2); similar holes on the shoulders of the Peplos Kore would have held comparable additions (cf. fig. 1b).[6]

Male figures could also rate this treatment. The so-called Ilissos Kouros in Athens (circa 500) once had a metal fastener of some kind bridging the two edges of his short mantle symmetrically worn over both shoulders (fig. 3). As late as approximately 311 B.C., the Alexander Sarcophagus from Sidon, on the long hunt side, shows Alexander with a deep and narrow indentation encircling his curls, probably for a metal circlet like the "diadem" found in the Royal Tomb at Vergina. Other possibilities are metal wreaths, some of which, in gold, have been recovered from Macedonian graves, and one of which adorned the head of the Apollo on the East Frieze of the Parthenon (fig. 4). Another may have rested on the partly balding head of the Centaur attacking the bridesmaid on the West Pediment of the Temple of Zeus at Olympia. The festive accoutrements would have made the brutality of the scene even more apparent.[7]

The real wreaths worn at banquets and other celebrations were probably perishable, made of leaves rather than gold foil, and the latter kind may have been reserved for the dead, so that the examples cited might not be entirely appropriate for the realistic category. Quite pertinent, however, are the many examples of weapons added in metal to stone figures, both in relief and in the round.

FIG. 3

The Ilissos Kouros. Athens, National Museum 3687. Photo: DAI Athens.

FIG. 4

Parthenon, East Frieze, slab VI. Athens, Akropolis Museum. Photo: DAI Athens.

The oldest example may be the Nikandre from Delos, one of our earliest extant marble statues (circa 650–630 B.C.), whose fisted hands are pierced by tiny holes for metal attachments. Since the inscription engraved on the skirt mentions dedication to the far-darting deity, it has been suggested that a bow and arrow in metal were in fact added to the composition, to identify the goddess Artemis in the stone figure. The observation that the holes do not run through the entire hand and thus are unsuitable to hold long weapons applies to only the left fist, not to both, and therefore I find it unlikely that the Nikandre should be visualized as grasping the leashes of two lions or a floral offering. Later examples are quite numerous, and the added weapons may be swords, spears, javelins, and even shields and helmets. A full bronze cuirass (and perhaps also a helmet) was given (in the late fifth century?) to the Pelops on the East Pediment of the Temple of Zeus at Olympia, perhaps to hide damage to the original surface. The addition cannot be dated precisely, since the temple and its sculptures underwent serious repairs at various times during their existence; it can, however, be proved by the attachment holes above the pubic hair and around the area of the armpit. Metal cheek pieces at the least are suggested by the holes drilled at Pelops' temples.[8]

In friezes, metal additions can be expedient where different layers of superimposed figures are rendered, and the

FIG. 5

Parthenon, Metope South 1 (in situ). Photo: DAI Athens.

weapons cannot be painted over or carved across overlapping figures. Several instances of this practice occur on the North Frieze of the Siphnian Treasury at Delphi. A goddess (Aphrodite, according to the new reading – once called Hera) bending over a fallen giant brandishes a spear that was partly carved in marble against the surface of another giant's shield, partly added in metal behind the goddess's head in a groove cut on the same shield and through her hand. Besides the weapon, the goddess was given metal earrings and perhaps other jewelry on her diadem. Another, fragmentary, bronze spear is still inserted before the face of the foremost among three giants who confront Apollo and Artemis on the same frieze; a fallen companion in front of them had an arrow planted in his chest. Within the same composition, the giant "Kantharos," fleeing in the opposite direction to avoid the lions of Themis' chariot, once held a metal sword in his hand, fastened with metal pins to his hand and the skirt of his chitoniskos; the empty scabbard is rendered in low relief against the background.[9]

FIG. 6

Slab 1006 from the Amazonomachy Frieze of the Mausoleum at Halikarnassos. London, British Museum. Photo: British Museum.

Attachment holes are often the only evidence that a metal weapon was once included; the best example is provided by Parthenon metope South 1, which can be seen as a self-contained unit, the human perhaps on the verge of losing to the Centaur, until the hole near the groin of the latter is noticed from an oblique viewpoint (fig. 5). Originally, a long skewer or spear would have crossed the composition, from youth's hand to monster's hindquarters, thus making the situation immediately legible from the front, and balancing the odds.[10] From the fourth century, many examples of added weapons could be cited, but most significant are perhaps those that occur on non-Greek monuments, such as the Mausoleum at Halikarnassos, where several Amazons on the frieze were given metal weapons, probably battle-axes (fig.6). Greek workmen at the site would have been responsible for this feature.[11] In Athens, an elaborate example confirms the practice in gravestones – the Dexileos Stele. The funerary monument for one of the five horsemen who died in 394 at the Battle of Corinth was supplemented by a metal weapon held by Dexileos in his right hand and fastened on his thigh; it has recently been argued that the reconstructed length of the addition suggests a javelin (an *akontion*) rather than a spear. The attachment holes on the knight's head, usually taken to be for a wreath, are now considered to be for a "Boeotian" helmet with a low rounded calotte, such as is worn by one of the riders on the state monument commemorating the same battle casualties. The rough finish of Dexileos' hair would corroborate this explanation. A metal sword was inserted into the fist of the fallen warrior, blade pointing downward.[12]

The figures on this Attic stele provide an easy transition into our third category, the *practical*. Under this heading I include those objects that were added in metal because of technical expediency – they were easier to render in bronze than in stone –

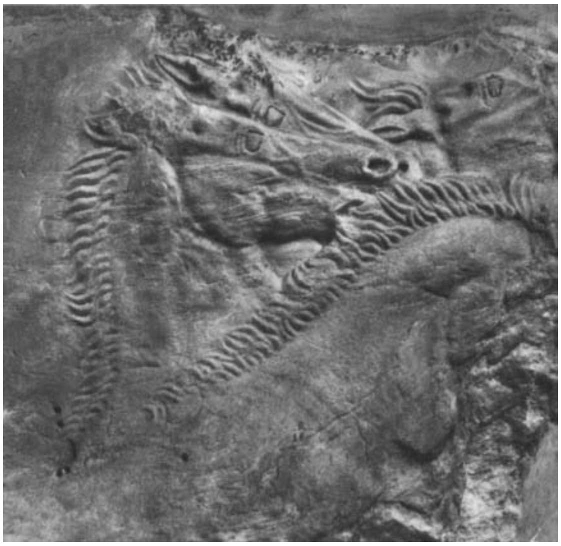

FIG. 7

Parthenon, South Frieze, slab XXX. Detail. London, British Museum. Photo: British Museum.

FIG. 8

Horse from the roof quadriga of the Mausoleum at Halikarnassos. London, British Museum 1002. Photo: British Museum.

although in reality they would have been of different materials. The most obvious of these are the thin baldric crossing the chest of Dexileos' opponent, supporting the empty scabbard at his side, and the horse's reins and head trappings. In real life both would have been of leather, although the baldric was occasionally, and the horse's bit always, in bronze.

Metal reins can be found in some of the monuments already cited, especially – ubiquitous – on the Parthenon Frieze (fig. 7). More important is to note the restrained use of metal attachments in the so-called Lycian Sarcophagus from Sidon. The two long sides, with the Lion and the Boar Hunt, respectively, show the riders certainly holding added javelins, but the reins may have been painted on, since attachment holes are not obvious. By contrast, the Alexander Sarcophagus from the same nekropolis had a plethora of metal attachments, not only weapons (including perhaps a small silver axe) but also horse trappings. One of the Mausoleum horses from the quadriga on the roof was found with part of its ancient bronze harnessing, which can be seen today in the British Museum (fig. 8).[13]

The practice of adding metal reins to horses can be traced back to the sixth century, to judge from the equestrian statues from the Athenian Akropolis. The so-called Persian Rider, Akropolis 606, provides a late Archaic example, but includes two other features pertinent to this category: the bronze buttons on the rider's boots, and the top-knot on the horse's forehead, which was made of wires (fig. 9).[14]

Hair is perhaps one of the features most understandably translated into metal attachments. The most startling example, to my mind, remains the disarrayed coiffure of a dying warrior (VI) from the later East Pediment (circa 480?) of the Temple of Aphaia on Aegina. The many attachment holes would be large enough for added

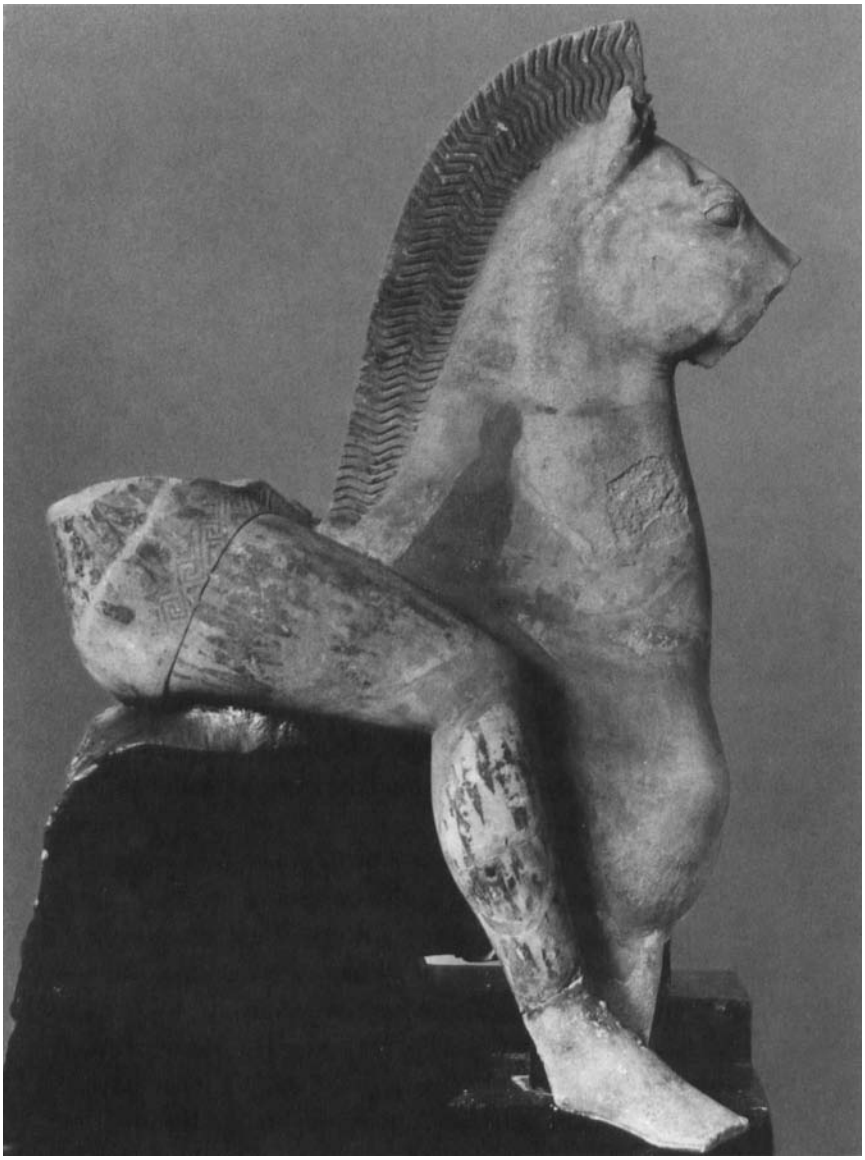

FIG. 9
"Persian Rider." Athens, Akropolis Museum 606. Photo: DAI Athens.

marble curls, but a sketch made by Cockerell at the time of discovery of the head shows it with two spiraling *lead* ringlets trailing over the forehead, effectively conveying the heat of battle. In the Severe period proper, a marble peplophoros in Corinth has a large number of holes drilled on her shoulders; if we connect them with imaginary lines, their alignment suggests long strands of hair streaming obliquely across the figure's back, as if displaced by motion (figs. 10a–b).[15]

Metal hair (in gold foil?) or even metal wigs are known from the Protoliterate and later periods in Mesopotamia, but the connection seems remote; wigs in different stones are occasionally found on Near Eastern statues, but the practice is different. One Greek metal wig has, however, survived in its entirety from the South Italian site of Cirò; it seems unlikely (because of the lack of correspondence between pegs and holes) that it once rested on the head of the akrolithic

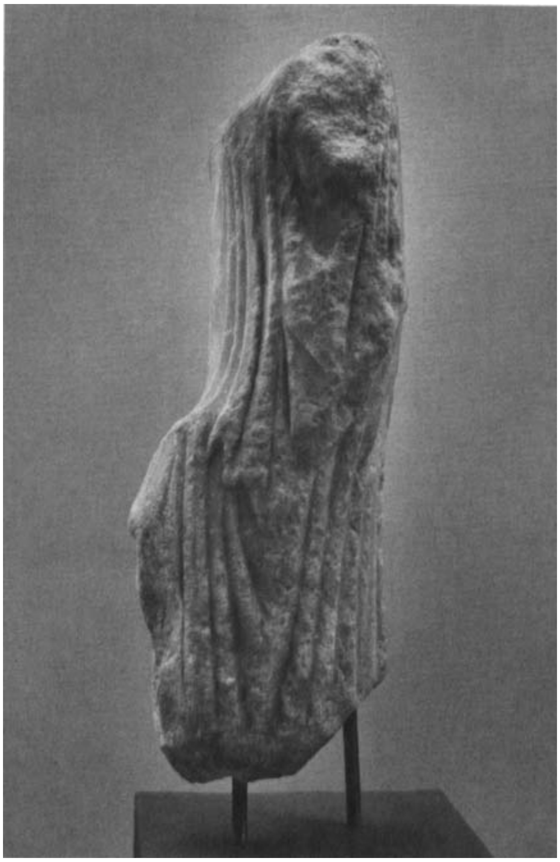

FIG. 10a

Peplophoros. Left side. Corinth Museum S 1577. Photos: American School of Classical Studies, Corinth Excavations.

FIG. 10b

Back of Peplophoros, figure 10a.

statue of Apollo Alaios (circa 460–440 B.C.?) recovered from the same site, but that the latter once had metal hair seems demonstrated by the drilling of its cranium above the temples (fig. 11).[16]

The Cirò Apollo also had inserted eyes and thus exemplifies one more form of metal attachment. The use of a bronze or copper capsule to contain eyes made of different media may be thought to have a technical reason, since it served to secure the eye within its socket; it should thus belong in my functional category. On the other hand, the excess metal of the capsule could be cut into a fringe to simulate eyelashes, and as such the rendering falls within my practical category. But a marble statue could easily have been given painted eyes and eyelashes, almost as effective and certainly less potentially dangerous than the added variety, for which cavities had to be carved into the head. It is therefore intriguing that Greek artists should have adopted this latter practice, albeit only occasionally (cf. figs. 13a–b).

A generally held assumption that the practice was inspired by hollow bronze casting may certainly be correct for late Archaic examples such as the Kritian Boy, but inserted eyes – although only the pupils, without metal surrounds – occur as early as the famous Akropolis Moschophoros, around 560 B.C., when large-scale bronze casting was in its infancy. That the inserted eyes were meant to convey the greater importance of the figure that had them is disproved by the

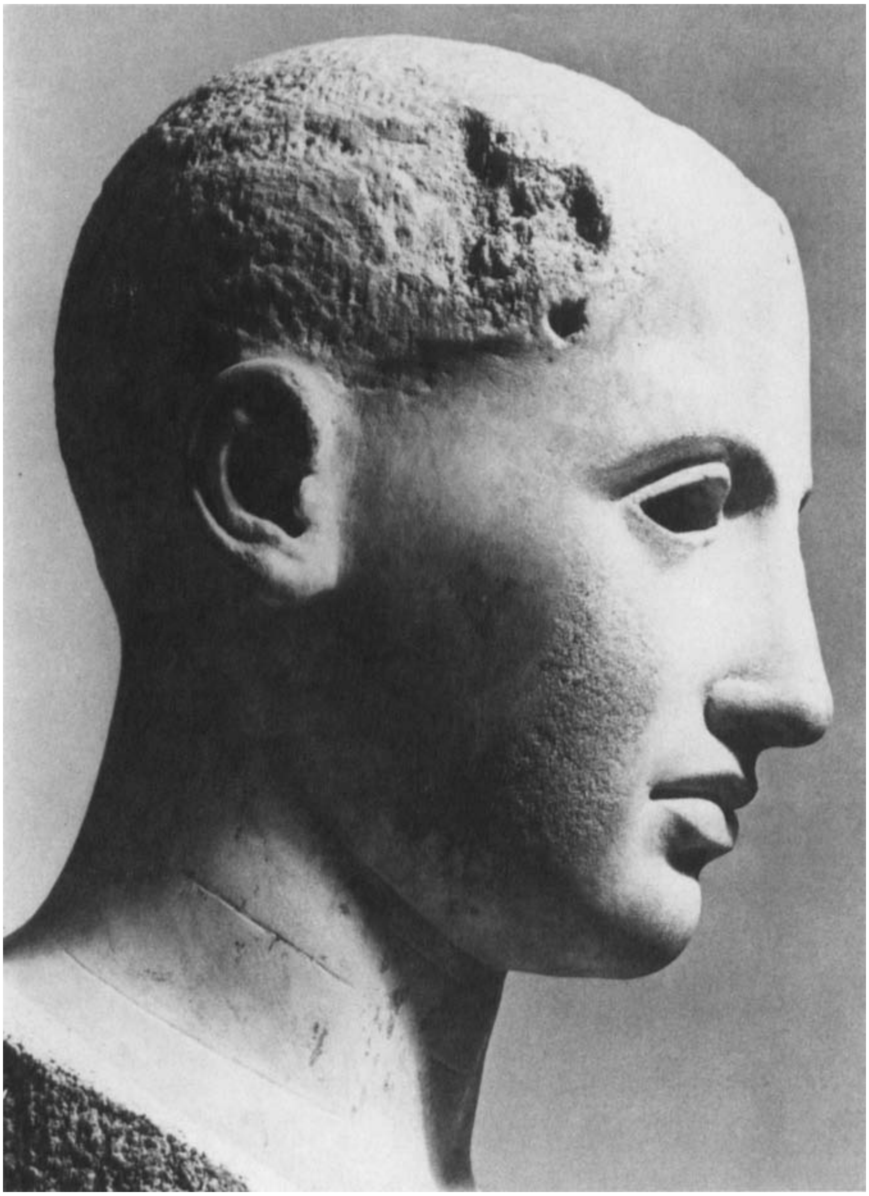

FIG. 11

Head of Apollo from Cirò. Reggio Calabria Museum 6477. Photo: Bryn Mawr College.

fact that an Archaic relief horse from the Akropolis also sports them. Gravestones occasionally use them, and a startling example in a head of Hygieia from Phineos, in Arkadia (second century B.C.?), shows that the practice continued into Hellenistic times.[17]

A possible inspiration for it can be found in Egyptian statues, which often had inserted eyes of great complexity and startling effect. They were of various types, but most had a copper or silver capsule, although only a few had it trimmed into eyelashes. A well-known example is the so-called Red Scribe in the Louvre, from the Fifth Dynasty (circa 2480 B.C.), but the practice continues into the New Kingdom and later. It is perhaps surprising that something as difficult as inserting eyes was attempted, while apparently no thought was given to adding a metal stylus into the scribe's hand. Another peculiar touch is

FIG. 12

Kore 673. Note head ornaments and arm attachment at right elbow. Athens, Akropolis Museum. Photo: DAI Athens.

FIG. 13a

Antenor's Kore. Front. Note the inserted eyes. Athens, Akropolis Museum 681. Photos: DAI Athens.

FIG. 13b

Side view of Antenor's Kore, figure 13a.

the addition of inserted nipples in copper, on limestone pieces.[18] This feature, which has been claimed also for some figures on the metopes of the Athenian Treasury at Delphi (circa 490 B.C.), would rightfully fall within my *bizarre category*. A second item in the same group could be the metal snakes added to the edges of Athena's aigis: They recur on the goddess of the Athenian Treasury metope with Theseus but can be found earlier on Akropolis 625, the so-called Endoios Athena (circa 530–525 B.C.). One more bizarre example, because unexpected, is the large snake entirely in metal added to Parthenon Metope East 2, on which Dionysos is depicted fighting together with a panther. Why the snake was not simply carved in relief, or rendered in paint, is uncertain, since it seems to occupy empty background space without significant overlap, to judge from the attachment holes.[19]

At the end of our review, we should again ask the question of possible inspiration or parallels for the entire practice of metal attachments. Elsewhere, I know of only one truly comparable instance of such additions, surprising because limited to one site and one type of figure, and therefore perhaps of Greek inspiration rather than vice versa. On the Persian reliefs at Pasargadae, especially from Palace P, the figure of the king is singled out by metal ornaments, probably in gold, fastened to his drapery. Since Pasargadae was built essentially under Cyrus the Great (559–530/529 B.C.), these are among the earliest examples we have, if we except the Delian finds. This situation is not readily explainable, and more research is needed.[20]

Besides the case of the wooden images already mentioned, for which clothing and jewelry would have been removable and understandable embellishment, we may ask what other prototypes may have provided inspiration to the Greeks. Perhaps they derived the idea from metal additions to oriental luxury products, such as the Nimrud ivories. Several of them, for instance, show inlays in colored stones and details of costume in gold foil. On the other hand, we cannot assume that the impetus behind the Greek practice is based on purely realistic effects – a desire to make their statues be as close as possible to the living prototypes they reproduced – since metal ornaments and additions are attested also for architectural parts. Aside from Archaic akroteria and cutouts in bronze, which could have had their origin in technical expediency as well as in aesthetic preference, we should mention the gold tassels filling the spaces between echinos and volutes in place of the traditional carved palmettes, and the metal "eyes" on the Ionic capitals of the North Porch of the Erechtheion, as well as the stars centered on the coffers of the same structure. The frame of the North Door to the temple was also decorated with carved rosettes having a metal heart. The total impression is obviously one of wealth and luxury, although comparable effects could have been obtained with gilding and paint, as suggested by the solid-core rosettes used in Roman times for the replacement lintel over the same North Door.[21]

In closing, I want to mention one other form of metal attachment that deserves further investigation: the so-called *meniskoi*. It has always been taken for granted that the bronze or iron rods often preserved on the heads of the Akropolis korai or other Archaic statues were to prevent birds from perching on the marbles, thus defiling and damaging them. The idea, and the name, meaning "crescent moon," have been derived from Aristophanes' *Birds*, vv. 1114–1117. Various solutions have been proposed to the problem of the form these bird-repellents must have assumed, from the simple rod without additions, to that of a full moon disc or a moon crescent, to a complete umbrella. The history of scholarship on this issue has been summarized by Jody Maxmin and can be usefully reviewed in her article. I only wish to add a few comments of my own.[22]

Any form of finial topping the rod on the heads of korai and kouroi would easily qualify for my bizarre category, were it only meant to keep away the birds. The practice, for unexplained reasons, seems largely limited to the Archaic period and confined to marbles, although bronzes could equally be defiled by these animals. I am also struck by the fact that the spike, or its attachment hole, is not always present, even on statues that would have stood outdoors, and that those that retain it are primarily from Athens or Attica in general – an area that seems particularly fond of metal attachments. The fourteen korai (and a Nike) listed by Maxmin as displaying a "meniskos" are from the Akropolis. Superficial statistics indicate there are only ten "meniskos" wearers out of seventy-eight potential candidates among the kouroi listed by Richter (excluding statuettes and counting only the preserved heads); of those ten, only one is not Attic – the head from Thasos in Copenhagen. Maxmin lists at least fourteen, but some of them are not kouroi. One, the Rampin Horseman, retains only the hole with traces of lead, but no spike. It has been suggested to me that the attachment might have been not for a "meniskos" but for a star, as identifying attribute for one of the Dioskouroi and applicable also to the Rampin's companion.[23]

Among the korai, some of the preserved rods are massive, yet they may never have held a topping ornament; other metal spikes occur in conjunction, lined up atop the diadem, and are so big as to suggest that considerable strength was necessary for whatever they originally supported; yet the single rod on the summit of the cranium would have sufficed to keep the birds away (figs. 12, 13a–b). In architecture, the idea of a moon of whatever shape surmounting the

Vogelabwehr seems untenable, yet holes on the Olympia metopal sculptures (but not on the pedimental statues!) have been interpreted as such repellents, and thin metal spikes are still preserved on the pedimental figures of the Temple of Artemis at Corfu, although some of them are in unlikely places for birds' nests or perches.[24]

Perhaps the most intriguing case is that of the sphinx surmounting the tall Attic gravestone in New York usually known as the Brother-and-Sister Stele; a wedge-shaped buildup occurs on the cranium, between the rod and the diadem, suggesting to me that some effort was made to provide support for the obliquely bent rod and to ensure the visibility of the contraption from ground level. Since such display would have been unnecessary in the case of a purely functional object, I can only conclude that the rod supported some form of ornament intended for public viewing. I propose to make a study of such head attachments and will report on them in the future.[25]

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Notes

Boardman:
J. Boardman, *Greek Sculpture: The Archaic Period* (London, 1978).

Richter:
G. M. A. Richter, *Korai: Archaic Greek Maidens* (London, 1968).

1 I have already published some comments on this topic, primarily in "Stone and Metal in Greek Sculpture," *Archaeology* 19 (1966), pp. 31–42 (see esp. pp. 38–41), but I shall here approach it from a different point of view, and with the needs of a varied audience in mind, ranging from pure archaeologists to pure scientists. My written text differs somewhat from my oral presentation and cannot be accompanied by as many illustrations, but the concepts expressed are basically the same. I am very grateful to Professor G. Roger Edwards for much help with both my thinking and my documentation.

2 Kore Akr. 673: see Richter, no. 117, figs. 368–372; Boardman, fig. 152.

Kore Akr. 679 (the Peplos Kore): Richter, no. 113, figs. 349–354; Boardman, figs. 115, 129. For general comments on this piecing technique, see S. Adam, *The Technique of Greek Sculpture in the Archaic and Classical Periods*. *BSA*, Suppl. 4 (1966), p. 81; cf. also her p. 47 and p. 66 for additional comments on the use of metal attachments and drill holes.

For the base of Phrasikleia, see E. Mastrokostas, "Myrrhinous: La kore Phrasikleia, oeuvre d'Aristion de Paros et un kouros en marbre," *AAA* 5 (1972), pp. 298–324, esp. fig. 16 on p. 317, and discussion on pp. 318–319. For other examples, see, e.g., the fastening of various parts of an Attic gravestone in New York, G. M. A. Richter, *The Archaic Gravestones of Attica* (London, 1961), p. 27, no. 37, figs. 102, 104. Also illuminating is the discussion, still current, about the connection between base and plinth of Akr. 681, the so-called Antenor's Kore; cf. H. Payne, *Archaic Marble Sculpture from the Acropolis*, 2nd ed. (New York, 1950), pp. 31–32, n. 2.

3 For comments on the Greek use of metal in architecture, see R. Martin, *Manuel d'architecture grecque* (Paris, 1965), pp. 155–162. On clamps, see his pp. 238–279, and cf. his n. 3 on p. 238 for the early use of clamps in Crete, Egypt, and the Orient; that the use of dowels is relatively late is mentioned on p. 279. On dowels, see his pp. 279–291, with comments on columns and use of dowels in the Classical period on pp. 291–296.

Delos kouros A 333; Boardman, fig. 59 (dated circa 580); B. S. Ridgway, *The Archaic Style in Greek Sculpture* (Princeton, 1977), pp. 64–65.

Hellenistic gravestone from Pergamon: E. Boehringer, "Pergamon," in *Neue deutsche Ausgrabungen im Mittelmeergebiet und im Vorderen Orient* (Berlin, 1959), p. 166 and fig. 33 on p. 165.

4 Kore Akr. 670: Richter, no. 119, figs. 377–379; Boardman, fig. 153. For the holes on the head of the Peplos Kore and other preparations for metal attachments, see esp. H. Schrader, E. Langlotz, and W.-H. Schuchhardt, *Die archaische Marmorbildwerke der Akropolis* (Frankfurt am Main, 1939), p. 46, no. 4. For ornaments on the korai in general, see Richter, pp. 11–12.

5 For Egyptian bronze cats with gold earrings, see, e.g., G. Steindorff, *Catalogue of Egyptian Sculpture in the Walters Art Gallery* (Baltimore, 1946), p. 147, nos. 664, 665, pl. 97.

For a Syrian female statuette in silver with gold ornaments, see, e.g., A. Spycket, *La statuaire du Proche-Orient ancien* (Leiden and Cologne, 1981), fig. 120; her fig. 96, a limestone statuette of the goddess Narundi, of the Akkadian period, shows a series of holes along the edge of both ears, but these are explained (pp. 144–145) as serving for the attachment of a gold revetment for the entire face. Another silver figurine with gold ornaments, from Ugarit, is shown in E. Strommenger and M. Hirmer, *5000 Years of the Art of Mesopotamia* (New York, 1964), p. 428, fig. 178. For a Hittite figurine of a god in rock-crystal, from Tarsus, whose headdress was separate and probably in gold, see, e.g., E. Akurgal and M. Hirmer, *The Art of the Hittites* (New York, 1962), pl. 53, below right; dated fifteenth to thirteenth century B.C.

Copper ornaments may, however, have embellished an Egyptian limestone statue of a seated man from Saqqarah, of the Fifth Dynasty (Cairo no. 35): W. Stevenson Smith, *A History of Egyptian Sculpture and Painting in the Old Kingdom* (Boston and London, 1946), p. 48. Only fragments of copper now remain in the holes bored into the short wig on either side of the face.

6 Ex-Knidian head: Richter, no. 86, figs. 270–274; Boardman, fig. 209. For a recent discussion of the piece, see F. Croissant, *Les protomés féminines archaïques* (Paris, 1983), pp. 71–82, pls. 17–18. Note that some of her curls are added in marble, although it would probably have been simpler to add them in metal; her eyes were also inserted separately.

Hera head from the Parthenon: F. Brommer, *Die Skulpturen der Parthenon-Giebel* (Mainz, 1963), p. 92, no. 7, pls. 134–135. The head had also been considered male and attributed to the Helios on the same gable, but the addition of a newly found fragment proves that it was turned to the right (thus incompatible with the Helios), and it is likely to be female: A. Mantis, "Neue Fragmente von Parthenonskulpturen," in H. Kyrieleis, ed., *Archaische und Klassische griechische Plastik*, vol. 2 (Mainz, 1986), pp. 75–76, pl. 106.2–3.

Nike of Archermos: Richter, pl. XIVa; Boardman, fig. 103. For a recent discussion, see B. S. Ridgway, "The 'Nike of Archermos' and Her Attire," in J. Boardman and C. E. Vaphopoulou-Richardson, eds., *Chios: A Conference at the Homereion in Chios, 1984* (Oxford, 1986), pp. 259–274. An even earlier example from the Cyclades could be the colossal marble Apollo dedicated by the Naxians, but there is still some dispute over the nature and chronology of the added metal ornaments; cf. Boardman, fig. 60 (dated circa 580–570; too late?); Ridgway (note 3), p. 65, n. 22. Certainly late Archaic statues from Delos show a great number of metal ornaments, thus suggesting that the practice was well entrenched there; see, e.g., kore Delos A 4064, with metal buttons for her chiton sleeves, as well as a necklace and other ornaments: Boardman, fig. 181; or the Leto from Delos, Athens, National Museum 22, with chains fastening her mantle and pendants for her necklace: Richter, no. 148, figs. 472–475. By contrast, East Greek statues do not, on present evidence, seem to have used metal attachments; this point needs further investigation.

Nike from Paros: B. S. Ridgway, *The Severe Style in Greek Sculpture* (Princeton, 1970), pp. 36–38, figs. 56, 58; A. Kostoglou-Despinis, *Problemata tes parianes plastikes tou 5ou a.p. Ch.* (Thessalonika, 1979), p. 196; R. Tölle-Kastenbein, *Frühklassische Peplosfiguren: Originale* (Mainz, 1980), pp. 264–266, no. 43d, pls. 173–175.

On the Peplos Kore, besides the references cited above (notes 2 and 4), see also B. S. Ridgway, "The Peplos Kore, Akropolis 679," *Essays in Honor of Dorothy Kent Hill. JWalt* 36 (1977), pp. 49–61, and, more generally, "The Fashion of the Elgin Kore," *GettyMusJ* 12 (1984), pp. 29–58.

7 Ilissos Kouros, Athens, National Museum 3687: Boardman, fig. 149; Ridgway (note 3), pp. 75, 82. For a drawing of the possible metal fastener, see I. K. Konstantinou, *Deltion* 14 (1931–1932), pp. 41–56. For a recent discussion of draped male figures in the Archaic period, see B. Barletta, "The Draped Kouros Type and the Workshop of the Syracuse Youth," *AJA* 91 (1987), pp. 233–246; the Ilissos kouros, no. 35 on her list, seems to be the only one with metal attachments, probably because the majority of the examples are from East Greek or Magna Graecian areas, which do not seem to have favored the practice.

Alexander Sarcophagus, circlet on rider's head: V. von Graeve, *Der Alexandersarkophag und seine Werkstatt* (Berlin, 1970), p. 58, pls. 48, 51.1.

Circlet from Vergina: M. Andronikos, *Vergina: The Royal Tomb and the Ancient City* (Athens, 1984), pp. 171–175, figs. 138–139; see also his fig. 137 on pp. 172–173, and text on p. 171, for a gold wreath from the same tomb. For the controversy over whether the circlet constitutes a royal diadem, see the contributions by E. A. Fredricksmeyer and W. M. Calder III, in *AJA* 87 (1983), pp. 99–103, with reference to previous discussions.

Apollo on the East Parthenon Frieze: F. Brommer, *Der Parthenonfries* (Mainz, 1977), E VI.39, p. 119 (described as the attachments for a possible laurel wreath), pls. 178, 182.

Group from the West Pediment at Olympia (figures H and I): B. Ashmole and N. Yalouris, *Olympia: The Sculptures of the Temple of Zeus* (London, 1967), figs. 110–111. That the woman in the grasp of the Centaur is a bridesmaid, and not the bride herself, is argued by P. L. Grunauer, "Der Westgiebel des Zeustempels von Olympia: Die Münchner Rekonstruktion, Aufbau und Ergebnisse," *JdI* 89 (1974), pp. 45–48.

8 Nikandre, Athens, National Museum 1: Boardman, fig. 71 (the floral or the lion lead is preferred for the metal addition); Richter, no. 1, figs. 25–28; Ridgway (note 3), pp. 86–87 and bibl. on p. 115.

Pelops from the Olympia Pediment: Ashmole and Yalouris (note 7), p. 13, figs. 46–47, 49.

9 Siphnian Treasury: for the new readings of the names, see Y. Brinkmann, "Die aufgemalten Namenbeischriften am Nord- und Ostfries des Siphnierschatzhauses," *BCH* 109 (1985), pp. 77–130. For illustrations of the figures cited in my text, see, e.g., R. Lullies and M. Hirmer, *Greek Sculpture*, 2nd. ed. (New York, 1960), figs. 50–51.

10 Parthenon Metope South 1: F. Brommer, *Die Metopen des Parthenon* (Mainz, 1967), pp. 71–76, esp. p. 74, pls. 155–157.

11 Mausoleum frieze, Amazonomachy: see, e.g., B. Ashmole, *Architect and Sculptor in Classical Greece* (New York, 1972), p. 177 and fig. 205; p. 182 and fig. 212. The use of metal additions seems, however, rather restrained, or perhaps confined to the work of certain hands.

12 The most recent discussion of the Dexileos Stele is S. Ensoli, *L'Heróon di Dexileos nel Ceramico di Atene: Problematica architettonica e artistica attica degli inizi del IV secolo a.C.* (Rome, 1987), esp. pp. 200–213 for a discussion of the metal attachments; see fig. 20 on p. 203 for a drawing of the relief with all such elements added.

13 Lycian Sarcophagus: B. Schmidt-Dounas, *Der lykische Sarkophag aus Sidon. IstMitt*, Beiheft 30 (1985), p. 18, pls. 3.2, 4.1; p. 22, pls. 7, 9; cf. also pls. 18–19, for the short side with Kaineos, whose weapon was added separately. The sarcophagus, dated 390–385 B.C., is considered not at all Lycian, but eclectic and Sidonian, with Egyptian elements. Few comments are made there about metal attachments; but cf. G. Mendel, *Catalogue des sculptures grecques, romaines et byzantines*, vol. 1 (Istanbul, 1912), pp. 158–171, esp. p. 159.

For the Alexander Sarcophagus, see von Graeve (note 7), passim.

Mausoleum horse: G. Waywell, *The Free-Standing Sculptures of the Mausoleum at Halicarnassus in the British Museum: A Catalogue* (London, 1978), p. 86, pl. 5, and pl. 11.22.

14 "Persian Rider," Akr. 606: Schrader, et al. (note 4), pp. 225–228, no. 313, pls. 138–139; Ridgway (note 3), pp. 142, 147. For a recent discussion on the interpretation, see R. A. Stucky, "Überlegungen zum 'Perserreiter,'" *AntK* 25 (1982), pp. 97–101. For a discussion of the metal remains, see K. D. Morrow, *Greek Footwear and the Dating of Sculpture* (Madison, 1985), p. 38 and pl. 39 on p. 34; she argues that the type of footwear is imaginary, perhaps to emphasize the "foreignness" of the representation: see her p. 191, n. 44. On metal attachments to footwear in general, see also pp. 25–26, and pl. 22 on p. 31. For another rider from the Akropolis having metal reins, see Boardman, fig. 165.

15 Warrior VI, from Aegina: D. Ohly, *Die Aegineten*, vol. 1. *Die Ostgiebelgruppe* (Munich, 1976), pp. 75–82; for Cockerell's sketch, see Ohly's fig. 67 on p. 76; for newly found metal locks, see his fig. 70 and cf. p. 78, n. 16. On the latest chronology for the Aegina temple, see M. B. Moore, "Aegina, Aphaia-Tempel, VIII: The Attic Black-Figured Pottery," *AA*, 1986, pp. 51–93.

Corinth peplophoros: B. S. Ridgway, "A Peplophoros in Corinth," *Hesperia* 46 (1977), pp. 315–323. R. Tölle-Kastenbein (note 6), pp. 259–261, no. 43b, pl. 170, prefers to see the holes as serving for the attachment of wings, despite their abundance (cf. her p. 261 and n. 542), but the idea seems unlikely, both technically and thematically.

16 For the addition of hair in gold foil(?) to a marble head from Uruk, of the Protoliterate period (circa 3000 B.C.), see Strommenger and Hirmer (note 5), p. 386, and figs. 30–31 (dated to the third quarter of the fourth millennium B.C.); for the gold wig found in the Royal Cemetery at Ur, see her pl. XV, p. 399 (dated to the end of the 27th century B.C.). Although the Mesopotamians favored composite sculptures with inlays of various kinds, the "realistic" use of added metal ornaments does not seem to have been popular. For an Old Babylonian diorite statuette from Ur, with possible metal horns added, see Spycket (note 5), pp. 234–235; cf. also her figs. 174a–b for a steatite wig from Tello, in the Louvre, and her fig. 145, pp. 213–214, for a limestone statuette with steatite hair, from Iran, dated to the last centuries of the third millennium. I owe this bibliographical reference to R. S. Ellis.

Cirò Apollo: E. Langlotz and M. Hirmer, *The Art of Magna Graecia* (London, 1965), pls. 118–119. Ridgway, *Severe Style* (note 6), fig. 158, pp. 122–123, n. 19, with bibl. on p. 129.

17 For Greek inserted eyes, see, e.g., Richter, p. 12 and pl. IVe (for bronze eyelids and eyelashes); cf. Antenor's Kore, Akr. 681, with inserted eyes in rock crystal: Richter, no. 110, figs. 336–340; Boardman, fig. 141. For the Kritian Boy, Akr. 698, see G. M. A. Richter, *Kouroi: Archaic Greek Youths*, 2nd ed. (New York, 1960), no. 190, figs. 570–574; Boardman, fig. 147. For the Moschophoros, Akr. 624, see Boardman, fig. 112 and frontispiece. A late bronze like the Peiraieus Apollo (Boardman, fig. 150) still has eyes of solid bronze, but inserted eyes occur in a sphyrelaton at Olympia, Boardman, fig. 134, dated circa 580 B.C.

Horse relief from the Akropolis, Akr. 1340: Schrader, et al. (note 4), p. 390, no. 476, pl. 200; the relief is grouped with other carved slabs that are attributed to the so-called Peisistratid Temple, but it cannot belong with them because of its different thickness.

For a gravestone figure with inserted eye, see G. M. A. Richter, *Catalogue of Greek Sculptures in the Metropolitan Museum of Art* (Cambridge, Mass., 1954), p. 18, no. 22, pl. 22c; dated first quarter of the fifth century B.C.

Head of Hygieia from Phineos: *BCH* 83 (1959), p. 626, fig. 14; cf. Ridgway (note 1), fig. 30.

18 For the Egyptian forms of inlaid eyes, see A. Lucas, *Ancient Egyptian Materials and Industries*, 4th ed. (London, 1962), pp. 98–127, where the various types are grouped. For the Red Scribe in the Louvre (inv. no. 2962) see Smith (note 5), p. 47; he does not comment on its inserted copper nipples, which were, however, verified by autopsy, and confirmed by Professor M. J. Mellink, who kindly gave me her notes. At the time this paper was delivered, Dr. Arielle P. Kozloff, from the audience, pointed out that the Egyptian practice of inlaying eyes within an outer metal rim would provide a realistic touch, corresponding to makeup lines. She also asserted personally to have observed attachment holes in the hands of scribe statues in the Cairo Museum, presumably for the addition of a metal stylus, and other evidence for metal attachments elsewhere, although she concurred that these details have not received proper mention in the literature. The stylus could have been a reed, as in real life.

For an unusual example of inserted eyes in an Assyrian statue of king Shalmaneser III (858–824 B.C.), from Nimrud, see Spycket (note 5), fig. 236 and p. 366; Mesopotamia had a very long tradition of inserted eyes during the third millennium B.C., but the practice seems to have been discontinued later and is not likely to have influenced the Greeks. Bitumen, rather than metal, was most often used to fasten the eyes into their sockets.

19 Athenian Treasury Metopes, inserted nipples: P. de la Coste Messelière, *FdD* 4.4 (1957), p. 21, n. 3. Even some freestanding statues from the Archaic period may have this feature, but they need further investigation.

Metope with Athena and Theseus ("Sacra Conversazione"): Boardman, fig. 213.1. Metal snakes were probably also attached to the aigis of the Athena on the Siphnian Treasury, North Frieze: Boardman, fig. 212.1.

Seated Athena, Akr. 625: Boardman, fig. 135.

Parthenon Metope East 2: Brommer (note 10), pp. 23–24, pls. 42.2–3, 43.

There are unexplained metal remains on the buttock of a Naxian kouros (Naxos 5520), verified by autopsy, which might fall into my bizarre category; cf. Ridgway (note 3), p. 65 (with other comments). The statue is now published in G. Kokkorou-Alewras, *Archaische naxische Plastik* (Munich, 1975), p. 97, K. 27 (dated shortly before the mid-sixth century); cf. also N. Zaphiropoulos, *Deltion* 17 (1961–1962), Chronika, Naxos, p. 271, pl. 324.

20 Metal attachment at Pasargadae: C. Nylander, *Ionians in Pasargadae* (Uppsala, 1970), pp. 124 and 149; cf. fig. 44a on p. 125. For other additions (probably in precious metals), again on royal figures alone, at Persepolis, see A. B. Tilia, *Studies and Restorations at Persepolis and Other Sites of Fars*, vol. 2 (Rome, 1978), pp. 60–61 (crowns; cf. p. 58 and n. 3), p. 65 (necklace, bracelet, earring pendant).

21 Wooden statues: see, e.g., Ridgway (note 3), pp. 21–26; also H. V. Herrmann, "Zum Problem der Entstehung der griechischen Grossplastik," in *Wandlungen: Studien zur antiken und neueren Kunst.* Festschrift E. Homann-Wedeking (Waldsassen-Bayern, 1975), pp. 35–48.

Nimrud ivories with gold foil and inlays: see, e.g., Strommenger and Hirmer (note 5), pl. XLII, dated to the last quarter of the eighth century B.C. and considered Phoenician.

For the use of bronze in architecture, see, e.g., B. S. Ridgway, "Notes on the Development of the Greek Frieze," *Hesperia* 35 (1966), pp. 188–204, esp. pp. 190–191, nn. 13–14; cf. also my *Archaic Style* (note 3), p. 217 and bibl. on p. 223 (akroteria); p. 229, n. 7 (metopes); pp. 255–256 (friezes). For periods later than the Archaic, see A. Burford, *The Greek Builders at Epidaurus* (Liverpool, 1969), p. 215.

For the Erechtheion details, see J. M. Paton, ed., *The Erechtheum* (Cambridge, Mass., 1927), pp. 82–85 (capitals), p. 89 (coffers), pp. 101–103 and esp. n. 1 on p. 102 (door frame and replacement lintel). See also E. M. Stern, "Die Kapitelle der Nordhalle des Erechtheion," *AthMitt* 100 (1985), pp. 405–426.

22 J. Maxmin, "Meniskoi and the Birds," *JHS* 95 (1975), pp. 175–180. See also R. M. Cook, "A Supplementary Note on *Meniskoi*," *JHS* 96 (1976), pp. 153–154. I am deeply indebted to G. Roger Edwards, who has generously put at my disposal his bibliography on the subject and has discussed his ideas with me.

23 For the korai listed by Maxmin (note 22), see her n. 13 on p. 178; for the kouroi, her n. 16 on pp. 178–179. My own calculations are based on a perusal of Richter's plates in *Kouroi*; the head from Thasos in Copenhagen is her no. 109, figs. 328–329, 334.

For the Dioskouroi wearing a star above their heads, see *LIMC* 3 (1986), s.v. (A. Hermary), e.g., nos. 10, 17, 80, 157; the Rampin horseman is discussed under no. 22. The idea of a star headdress for the Akropolis riders belongs to G. Roger Edwards, but would strengthen my own theory: *Archaic Style* (note 3), pp. 141–142. Contra, see Boardman, fig. 114.

24 Korai with heavy rods *and* "meniskoi": Akr. 670 (note 4); Akr. 673 (note 2). Akr. 681, Antenor's Kore (note 17), has a particularly heavy "meniskos" rod; cf. also Kore Akr. 682, Richter, no. 116, figs. 362–367; Boardman, fig. 151.

"Meniskoi" on the Olympia metopes: for the original idea, see E. Petersen, "Vogelabwehr," *AthMitt* 14 (1889), pp. 233–239; and cf. G. Treu, *Olympia*, vol. 3. *Die Bildwerke in Stein und Thon* (Berlin, 1897), p. 153 and pl. 45.

For the use of "meniskoi" on the pediment of the Temple of Artemis at Corfu, see G. Rodenwaldt, *Korkyra: Die Bildwerke des Artemis Tempel*, vol. 2 (Berlin, 1939), pp. 17–18, n. 1.

25 Sphinx on the Brother-and-Sister Stele: Richter, *Gravestones* (note 2), no. 37, figs. 96–109, 190, 204. My study, now completed, appears in *AJA* 94 (1990).

Some Reflections on Tools and Faking

Peter Rockwell

My interest in the use of tools in stone carving is first as an artist and carver. I am fascinated by the ways others have used tools. For the same reason my interest in faking is primarily the problem of how or whether a perfect imitation of the work of another period can be made. A reproduction is not particularly interesting, as it is just a superficial copy, but the creation of a new work of any period is a more challenging exercise. One might say that having become a student of the techniques of marble carvers of the past, I cannot help being interested in the techniques of those in the present who are imitating the past.

My interest even took me so far as to produce a fake myself. That is not quite correct; my intention was to create a fake of the work of a well-known faker, Alceo Dossena. I once became enraged with a collector who came to my studio under pretense of being interested in my work but then turned out only to wish my help in obtaining a Dossena. Why not satisfy both of us by making a fake Dossena? I became so enamored of the project that I soon broke the cardinal rule of a good faker: never let on what you are doing. I could not resist telling everyone I knew that I was working on a fake of a faker.

Actually, I was not working on it, I was having someone else work on it and then planned to go over it at the end, adding the finishing touches, something that in fact I never did. This was, as far as I could tell, following Dossena's own technical practices. The carver I hired was of the Dossena "school." For accuracy, we used a plaster model of a head by one of Dossena's assistants, Gildo Pedrazzoli. Thus this was not a fly-by-night operation but a serious effort.

It was not just my talkativeness that stopped me. I was also stumped by some technical problems, which can be expressed as three questions. What do I know about Dossena's techniques? Is there any documentation available so that I can study them? Is it possible to make a good imitation of someone else's tool work?

In this paper I would like to reflect on these same three questions as they apply to Roman sculpture. Rather than the detection of fakes, I am concerned with the problems of making them, but I hope that this may be useful to those who wish to detect them.

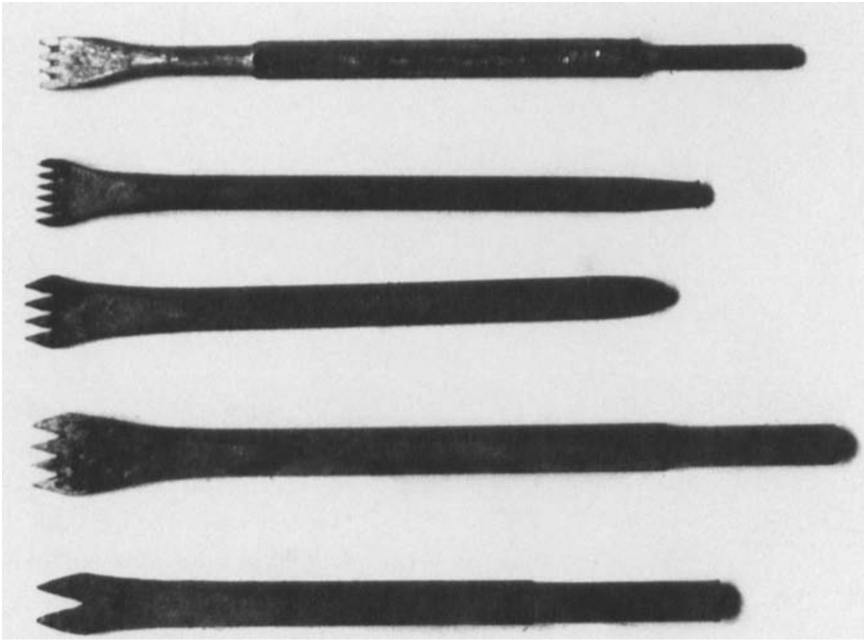


FIG. 1

Modern tooth chisels.
Photo: author.

In order to limit the topic to a manageable size, I will focus on the use of one tool, the tooth chisel, in the carvings of Aphrodisias and Rome. The choice of the tooth chisel is arbitrary, as any other chisel would show similar results.

Returning to the three questions as they apply to the particulars of the ancient use of the tooth chisel, my answers are all negative. In the first instance, we do not in fact have a clear knowledge of Roman tool use, for modern writers on ancient technique have a strong tendency to oversimplify tool usage so as to make it seem much more like modern usage than it really was. The answer to the second question is that we have no standard, reliable method of documenting tool usage on ancient carvings; the information we do have is therefore incomplete, unclear, sometimes inaccurate, and of questionable use for establishing a valid concept of ancient tool use. The third answer is that ancient tool use differs enough from modern practice that it is virtually impossible for a modern-trained carver to duplicate it. After analyzing Roman tool use for several years, I think that any modern carver would have to unlearn his modern technique and then learn Roman technique in order to make a technically competent fake.

From my working knowledge of tools, observations of ancient tool marks, and experiments in carving different types of white marble obtained from ancient quarries, I have got some feel for the variety of problems of carving the stones used by the Romans. When I bring this feel to current art historical and archaeological descriptions of ancient methods, I often have the impression of looking at something through the wrong end of a telescope. While the descriptions may not be factually inaccurate, they still somehow feel wrong. If I compare my experience with that of other carvers, I find the

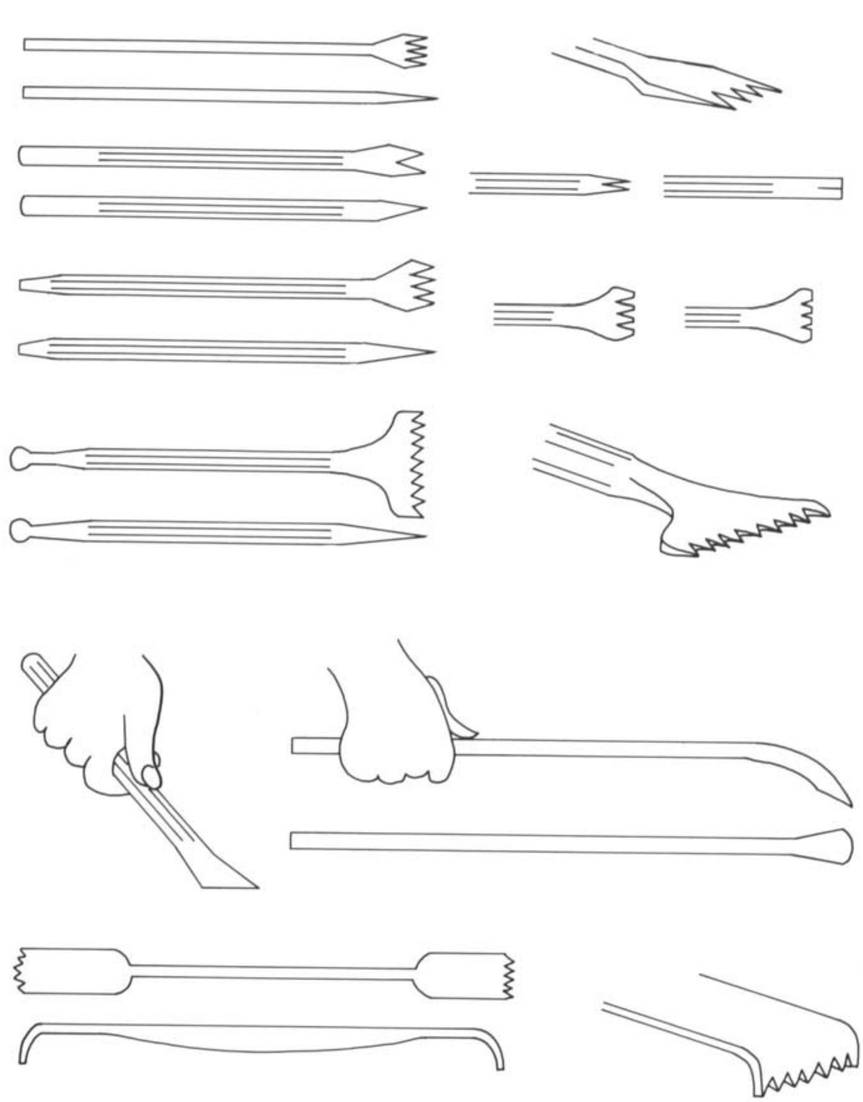


FIG. 2

Tooth chisels and scrapers. Drawing by author.

same reaction. The professionals who share my interest in ancient techniques are sometimes the fakers themselves, and they are obviously unlikely to publicize their findings.

To my knowledge, no standards have been established for documentation of tool marks of any period. Several years ago, the Soprintendenza alle Antichità di Roma issued a preliminary report suggesting certain methods, but they have not caught on. The only classes that I know of in identification of tool marks are given in Italy for restorers. I have seen flat chisel marks identified as those of a tooth chisel, or axe marks as those of a wire saw, and the confusion that exists around the running drill and its possible marks is quite incredible. On the other hand, most written descriptions of tool marks seem to admit no uncertainty about the subject. The result is that it is not possible to assume that any written description is accurate unless you trust the observer.

This is not a difficult situation to remedy. Photographs that include scale markers and documentation drawings that show where each kind of tool mark is found on the carving would allow tool marks to be analyzed and studied by anyone. Until this is done, however, we will not know enough about the variety and norms of Roman carving to provide clear descriptions of their technique.

The basic hand tools of marble carving are the point chisel, the tooth chisel, the flat chisel, and the round-headed chisel or roundel. The tooth chisel (figs. 1–2) is a flat chisel with notches in the cutting edge or a number of points set in a line so that they all strike the stone together. In fact there is a French form of the toothed axe that is precisely that, a group of points locked into a handle. In the United States this tool is called a tooth chisel, in England a claw chisel, and in Italy a *gradina*. Special forms of it are called *calcagnolo, dente di cane* (dog's tooth), and *martellina*. The variety of the Italian names shows that the tool takes different forms for different uses. It can be used for rough shaping, fine shaping, surfacing, and fine finishing. It can vary considerably in size and number of teeth. I have one four mm wide with two teeth, and one ten cm wide with fifteen teeth, as well as numerous variations in between. What I have seen of Roman tool marks suggests that the Romans had an equally wide range of tooth chisels.

The teeth of a tooth chisel can be pointed or flat. A *calcagnolo* has two pointed teeth set so that it is really like two point chisels bound together. A *dente di cane* has very short, flat teeth so that it seems like a flat chisel with a nick in the middle of the cutting edge. The teeth of the chisel become blunt with use. One can sharpen the edges on an abrasive stone, but one cannot sharpen between the teeth, so they become progressively flatter as the tool is used. In time, the effect is that a *calcagnolo* becomes a *dente di cane*. After hand sharpening no longer works, the teeth are redrawn to a point only when the tool is tempered by a blacksmith. The result is that a carver using the same tooth chisel in the same way can produce different marks on Wednesday from those produced on Monday.

The tooth chisel is normally the middle range tool. First the point chisel roughs out the form, then the tooth chisel carries on the work, and finally the forms are smoothed with the flat or the roundel (fig. 3). This description is generally true of marble carving, whatever the period.

Like any other hand tool, a tooth chisel can be held at various angles to the plane of the stone. When roughing out a form with a heavy tool, one tends to hold it almost perpendicular to the surface and use a strong blow with the hammer. However, the tooth chisel held at such an angle and hit hard can bruise the stone. The finer the detail and the closer to the finish the cutting is, the lower is the angle

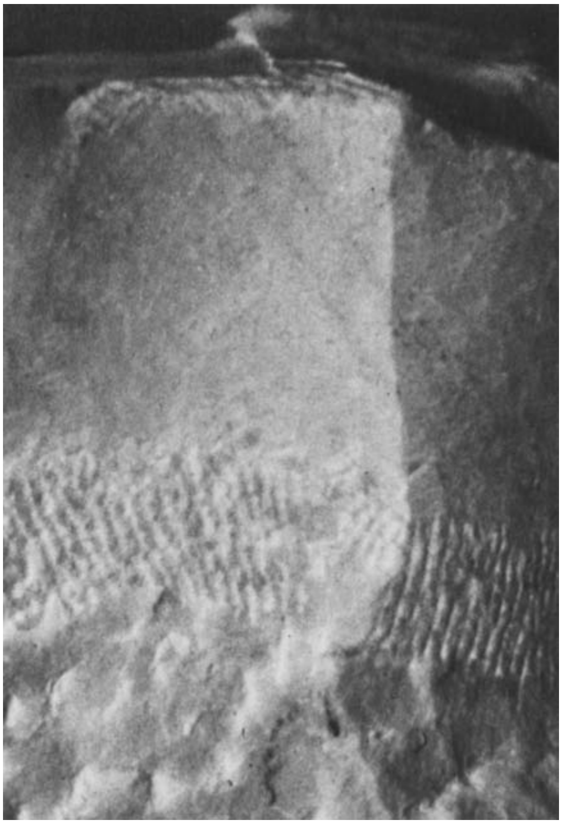


FIG. 3

Marks of the flat, tooth, and point chisels (from top to bottom) on Carrara marble. Photo: Victoria Starr.

FIG. 4

Detail from an unfinished carving by Benedetto da Maiano. Late fifteenth century. A tooth chisel was used as a rough shaping tool to block in the nose, cheek, and hair. Florence, Museo del Bargello. Photo: author.

at which the tool is held to the surface. Some white marbles, such as Thasos from the Vathy quarries, are very hard, and the angle of the tool must always be fairly high. Other, more agreeable marbles, such as Aphrodisias or Afyon, allow a wider variety of angle of attack. The way the tool is held, the force of the blow, and whether the tool is left to rest on the stone or is lifted between blows can vary according to the type of stone, the level of finish desired, and the type of work. Also, one should not forget that the type of hammer is another variant that affects tool use.

At least since the beginning of the sixteenth century, and probably earlier, the tooth chisel has been a shaping tool. The forms are roughed out with a point, and then a tooth chisel with two to four pointed teeth is used to rough out the smaller forms. For squaring a block, the tooth chisel will be employed less, for the forms are much more simple. It is used to cut away the rough ridges of stone left by the point. Carvers of flat work generally use wide chisels with flat teeth.

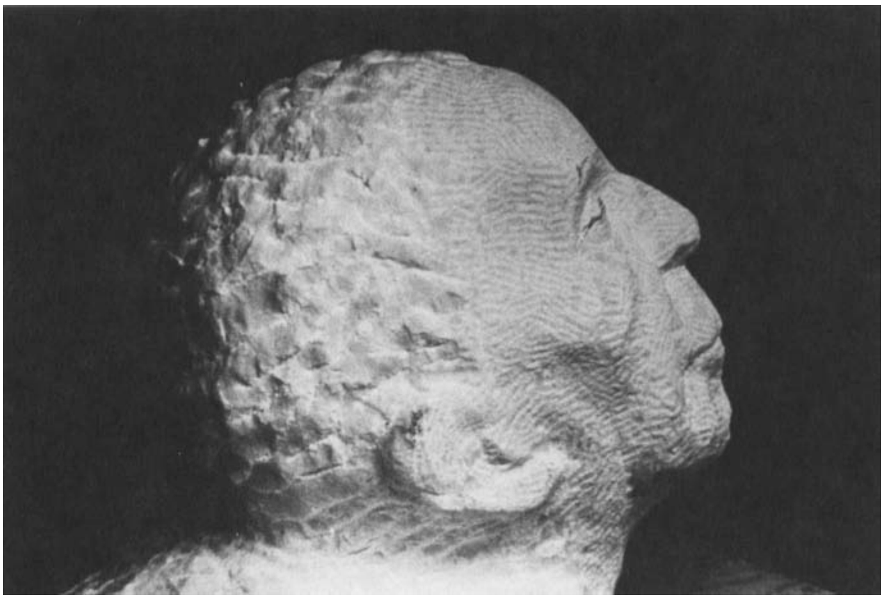
If one is carving a head, the basic shape is cut with the point. The initial division of hair from face and the first forming of the features is cut with the rough tooth. Then a tooth chisel with pointed teeth, closer together, shapes the features clearly. Next a tooth chisel with flat teeth will smooth the skin of the marble while cutting the more subtle undulations of the flesh. Finally a two-toothed *dente di cane* will work over details such as eyelids or lips. Only after most of the forms are well defined are the flat chisel and then the rasp used for

FIG. 5a

Tooth chisel marks on unfinished portrait by author. Photos: Victoria Starr.

FIG. 5b

Tooth chisel marks on portrait, figure 5a.



smoothing the surface. Cellini describes the process as cutting away successive skins of the marble. This description fits Michelangelo's unfinished works as well as those of other Renaissance sculptors (fig. 4). Photographs taken as the carving progressed on a portrait of mine show the passages of different tooth chisels (figs. 5a–b).

Some carvers, among whom Michelangelo is the outstanding example, will use flat-toothed chisels that are virtually notched flat chisels. They cross-hatch the surface to such a fine finish that there is no need for a flat chisel. The face of the Medici Chapel Madonna is a good example. Other carvers will use the tooth chisel to give a texture to the stone for a specific effect. Bernini's portrait of Costanza Bonarelli has the hair carved with a fine tooth chisel.

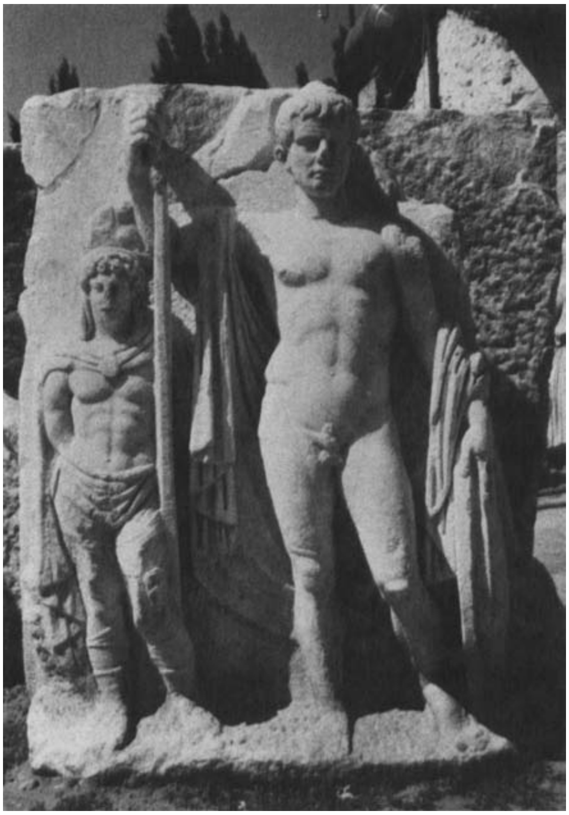
For Renaissance and later carvers, the tooth chisel is a versatile tool. It can provide the final surface for special effects. In marble carving it is always the primary middle-range tool for creating forms. The modern carver usually has more tooth chisels, and a greater variety of them, than any other type of tool.

My first examples of Roman work are three reliefs from the south portico of the first-century-A.D. Sebasteion of Aphrodisias. The first is an unfinished relief of an Imperial personage (figs. 6a–b). The body of the central figure, most of the legs, and part of the lower torso are tooth-chiseled. One can see that the carver was working from top to bottom so that the flat chiseling, which is probably the final surface, is moving down and gradually erasing the tooth chiseling (fig. 6c). The tooth-chisel work is close to the final surface. It does not, however, seem to be used for shaping forms. For example, the depressions between the forms of the muscles are cut with a round-headed chisel running along the depression. The tooth chisel just takes the rough marks of the point chisel off the form itself. There is no sign on this carving of the tooth chisel being used as a major form-cutting tool.

To move aside for a moment from Aphrodisias, a very clear example of the relationships of the point, tooth, and flat chisels on a large sculpture is the unfinished Barbarian in the Museo Gregoriano Profano of the Vatican. Looking at the back of the head, we see a succession of point to tooth to flat or round-headed chisels moving from back to front. The point chisel has carved the major forms of the head to a much further level than one would expect on a modern carving. The tooth chisel smoothed the bumps left by the point. A fairly wide, round-headed chisel was then used to cut the curves of the strands of hair. The front of the head shows that a finer round-headed or flat chisel then refined the detail of the hair. The tooth chisel was relegated to a position of cleaning up after the point, which is almost invisible on this carving. Again, it is not used in shaping forms.

The tooth chisel used on the Aphrodisias relief has wider teeth, but it seems to occupy roughly the same position. Aphrodisian marble being a very soft stone, a flat-toothed chisel can easily smooth out the marks of a point. On the body, the flat chisel does relatively little work, but on the drapes and hair it functions in a way similar to that seen on the Barbarian.

Returning to Aphrodisias, two other reliefs from the Sebasteion show the use of the tooth chisel in finished work, in both cases used for the background. On the Achilles and Penthesilea (figs. 7a–b) it is also used for the frame below the figures. On the relief of Herakles freeing Prometheus, the texture of the rocks of the background is suggested by the tooth-chisel marks. In fact, the treatment of the tooth



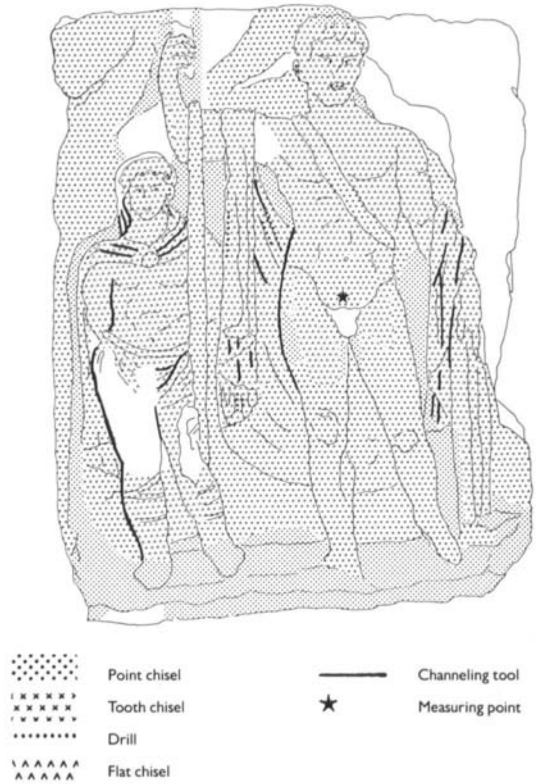


FIG. 6a

Unfinished relief of an Imperial personage. Aphrodisias, south portico of the Sebasteion. Photo: author.

FIG. 6b

Drawing of relief, figure 6a. Tool documentation. Drawing by Gianni Ponti.

FIG. 6c

Detail of relief, figure 6a, showing marks of flat, tooth, and round-headed chisels (from top to bottom). Photo: author.

chisel on these two reliefs is different. In the former, the tooth chisel was held at a low angle and hit lightly so that it cut a smooth surface, and the tooth marks are barely visible. On the Herakles relief, the tool was held closer to the perpendicular and hit considerably harder so that the surface is much rougher. The tool seems to be wider but with finer teeth than that used on either of the other reliefs. In both these reliefs the tooth chisel was being used as an interim tool for smoothing after the point and as a finishing tool. It did not, on the other hand, take much stone off, and it was not a shaping tool.

Incidentally, one should note that the differences between the uses of the tooth chisels noted here and their location on the reliefs can only be read in a combination of photographs and documentation drawings. The photos would be even better if they included a scale marker, but they do suggest a means of documentation that allows comparison with other monuments, which is an improvement over written description alone.

The Agora Gate in the section nearest the theater of Aphrodisias has several pieces of columns that were still standing when excavated. One has been left plain, without any carving being done after it was erected. From the top, the drum has two levels of point chiseling or point axing. The upper one is rougher than the lower. The bottom quarter of the drum is tooth-chiseled. It is easy to see from the difference between the second level of point chiseling and the tooth

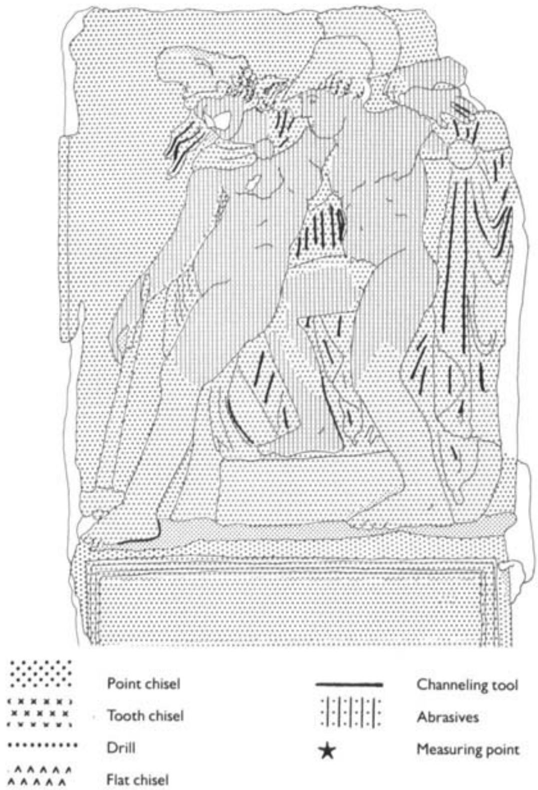


FIG. 7a

Relief of Achilles and Penthesilea. Aphrodisias, south portico of the Sebasteion. Photos: author.

FIG. 7b

Drawing of relief, figure 7a. Tool documentation. Drawing by Gianni Ponti.

chiseling that the latter is simply a smoothing away of the bumpy surface left by the point.

The column between the one described above and the wall has two blocks left standing. The work has been carried further because the fluting has been begun on the upper part. The earlier stage of work is on the lower block (fig. 8a). Here we see a succession of parallel vertical strips, about two inches wide, carved with a tooth chisel. The tool was a sharp-toothed chisel, probably with five teeth, which cut down the stone. The strips in between were cut with a tooth chisel that had more teeth, smaller and set closer together. The tool cut across the vertical line in short diagonal strokes. The effect is a column with alternating vertical stripes. Two incised lines, which mark the position of the space between the flutes, were marked vertically in the area worked by the finer tooth chisel. On the upper block, the flutes have been partially carved (fig. 8b). The lower part of the flute was shaped quite close to the final surface with very careful, fine-point chiseling. The upper part of the flute was smoothed with a slightly rounded flat chisel. Only an abrasive was needed to finish the flutes. There is no sign of a stage of tooth chiseling between the point and flat chisel work.

If we combine the observations on the two columns, we see the tooth chisel used in three stages on the column drum. First it was used to smooth the roughness left by the point chisel, then to cut vertical strips down the drum. Finally, working across the

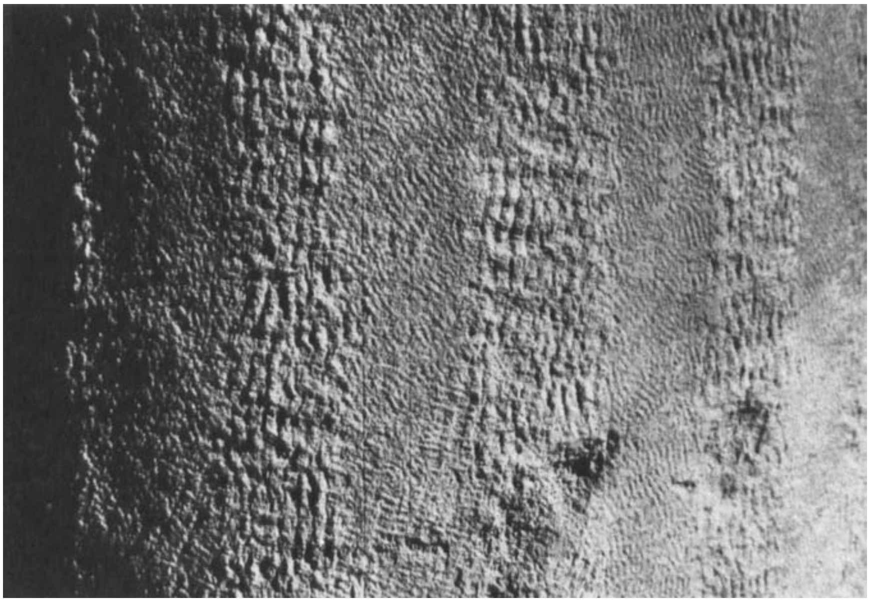


FIG. 8a

Unfinished column showing chisel marks. Aphrodisias, Agora Gate. Photos: author.

space between the strips, the carver made a surface on which the width of the fluting could be marked and which created a flat surface for the fillets. The tooth chisel was being used for shaping, but only a very little stone was taken off. It seems likely that the tooth chisel was used for the visual effect of the vertical strips, which helped the carver work step by step into the stone, and for the creation of a space that was smooth enough for the vertical incised lines. The real shaping was done by the point chisel in the beginning and in carving out the flutes. It almost seems as if the tooth chisel was considered a rough-working flat chisel rather than a separate tool with a function of its own.

This limitation in the use of the tooth chisel, which is virtually absent in small sculpture, is something I have always found remarkable about Roman carving – remarkable because it is so different from Renaissance and modern use. The modeling of form that I would expect to do with a tooth chisel was being done in Roman times by a combination of fine point chiseling and rough flat chiseling. The first place where I noted this is the Thiasos Sarcophagus from a tomb on Via Salaria. Now in the Museo Nazionale Romano, it is a beautiful example of quality carving on an unfinished Roman piece. Unfortunately, the sarcophagus has been in a crate for several years and may remain there for several more, but there are many other examples that show the same technique, both in Aphrodisias and in Rome. The small statue of Artemis from the sculptor's studio in Aphrodisias was carved with a point chisel and with various sizes of round-headed and flat chisels. There are no signs of the tooth chisel anywhere on the piece. One can see that the carver was used to treating the round-headed or flat chisel, about one to two cm wide, as a much rougher working tool than a modern carver would.

A more complete example is the lid of a hunting sarcophagus from the Braccio Nuovo of the Museo dei

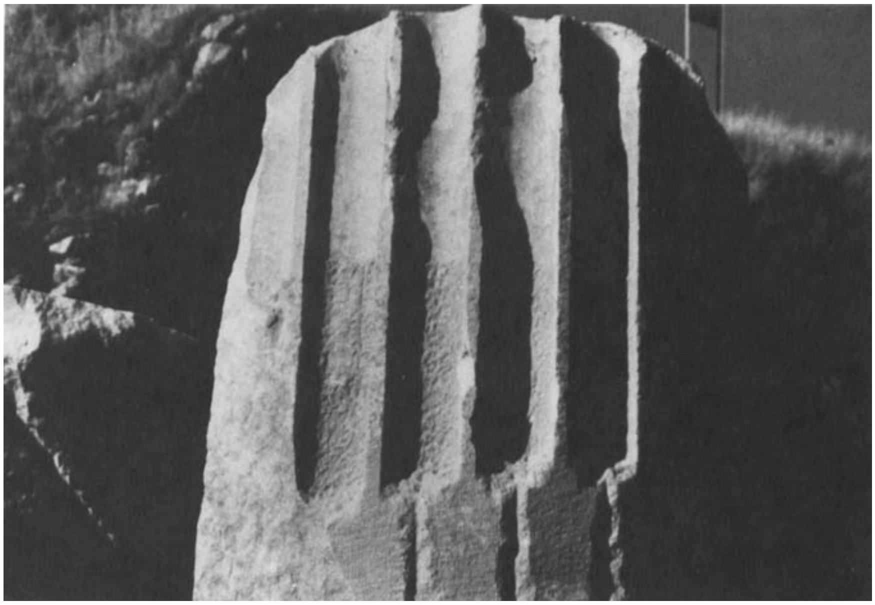


FIG. 8b

Unfinished column with flutes, figure 8a.

Conservatori on the Capitoline (figs. 9a–b). The left side of the lid (fig. 9a) was roughed out with a point chisel so that we can see the basic form of the composition without much in the way of details. The right side (fig. 9b) shows a later stage of the work. The forward parts of the figures, trees, and animals have been cut with a narrow, rather flat, round-headed chisel, while the places between the details were carved with fine-point chiseling. There are no marks of the tooth chisel. As for the Aphrodisian Artemis, the round-headed chisel was used as a shaping tool for details and as a smoothing tool. The tooth chisel as used in modern carvings was not used. Yet, as we see in the Vatican Barbarian, the tooth chisel was not unknown or unused on large sculpture. It would seem instead that it had a much more limited range of use than in modern carving.

I would now like to consider two large Roman monuments, the Arch of Trajan at Benevento and the Column of Trajan in Rome. Both these monuments have only very small areas left unfinished, so there is no question of finding a tooth-chiseled intermediate level. Both monuments have, however, tooth-chiseled surfaces that are finished.

On the arch, the flat surfaces below the two major reliefs in the passage were finished with the tooth chisel. The marks of the tool are so clear that it is possible to see that the surfaces were carved after the blocks were set in place. The carver was using strong blows to move the tool across the surface, so there are many marks of the tool biting into the stone. It is a finished surface done quickly, without concern for smoothness. The tooth-chiseled surfaces on the column are carved with a bit more care.

On the arch, this surface finish is only found on the flat surfaces. The columns and moldings are either cut with a flat

FIG. 9a

Unfinished sarcophagus lid. Left side. Relief roughed out with point chisel. Rome, Museo dei Conservatori. Photos: author.

FIG. 9b

Right side of unfinished sarcophagus lid, figure 9a. Second-stage work in which the round-headed chisel was used.

chisel or finished with an abrasive – it is not easy to tell which. The flat blocks all around the arch at the level below the sculpture all seem to be finished with a tooth chisel, although on the unprotected outer faces time, weather, and human hands have erased much of the finish.

Some of the sculpture on the external faces of the arch, especially at the higher levels, is in a very good state of preservation. On some of the figures of the frieze and the top level of reliefs, the condition is so good that the marks of the final surface finish are intact. Much of the surface of these figures shows very shallow parallel lines that appear to be made by a tool with pointed teeth set quite close together (fig. 10). These marks show no signs of the biting into the surface caused by the blow of a hammer on a tooth chisel. They are also shallower than I would expect from a tooth chisel. On the other hand, the direction of the movement of the tool is not inconsistent with a tooth chisel. In any case it is certain that they were made by some sort of toothed tool.

The same sort of marks are occasionally found on the Column of Trajan where the surface finish still survives (fig. 11a). Since, unlike the arch, there are areas obviously finished with a rasp (fig. 11b), it is worth comparing them. A surface finished with a rasp does not

FIG. 10

The Arch of Trajan, Benevento. Detail from the frieze showing marks of the scraper. Photo: author.

show consistently parallel lines. It is a scratchy surface on which the scratches are very fine, vary randomly in relative depth, are not parallel, and are closer together than those made by the toothed tool.

Before describing the tool that may have made these marks, I should explain that I have been coming across the same or very similar marks on monuments in Rome for several years. Principally working with Giovanna Martellotti of the C.B.C. restoration cooperative in documenting tool marks on the monuments being cleaned by this group, I have noted these same, very shallow parallel marks on the Ara Pacis and the Marcus Aurelius reliefs in the Museo dei Conservatori. The clearest example, however, is on the arch at Benevento. At various times we have assumed that they were made by a

FIG. 11a

The Column of Trajan, Rome. Detail of a Dacian, block 12. Horizontal lines on the background are made by a scraper. Photo: Claudio Martini.

FIG. 11b

Detail of Column of Trajan, figure 11a. Part of a leg of a Roman soldier, block 9. Marks were made by a rasp. Photo: Claudio Martini.

FIG. 11c

View from the inside of a window in the Column of Trajan, figure 11a. Tooth chisel marks. Photo: author.

toothed scraper or a very fine tooth chisel, and we still do not completely agree on how they were made.

In my opinion, the tool that made these marks was a toothed scraper, basically a tooth chisel with very fine, closely spaced teeth, bent at about a 30-degree angle some five cm behind the cutting edge, a bit like a small rake. This tool was not hammered but simply pushed back and forth across the stone. It was basically a tooth-chisel-like tool used as if it were a rasp. Scrapers have been used a great deal in northern Europe since medieval times. In France, especially, they are very popular with soft-stone carvers, but I have never seen them used by marble carvers. Yet, by filing a French soft-stone scraper to sharpen the teeth to points, I have been able to make a tool that reproduces the marks seen on the Roman marble carvings.

What we have here, then, is basically a variant of the tooth chisel used as a fine finishing tool. I have never seen signs of its use in Aphrodisias or on sarcophagi in Rome. So far it has only been found on monumental relief sculpture, and by no means on all of that. Only on the arch at Benevento is it the principal finishing tool on figures and drapery. On other reliefs it is used alongside and usually less frequently than the rasp. It is always possible, however, that once people start looking for it, it will be found on other types of sculpture.

The whole of the interior stairway of the Column of Trajan is finished with a tooth chisel, including the slots for the windows (fig. 11c). As is common with flat-worked surfaces, the corners and the edges of the block have a thin edge cut with the flat chisel. In the present context, it is interesting to note that we have on the column, and especially on the arch, toothed tools being used to finish both architectural flat surfaces and sculpture. At least in these cases we are dealing with carvers who see the toothed tool as a finishing tool that gives a pleasing quality to the final surface.

FIG. 11d

Detail of Column of Trajan, figure 11a. Heads of two Dacians, block 17. Background has been carved with a round-headed chisel. Photo: Claudio Martini.

The only unfinished area on the Column of Trajan, where one might hope to see the use of a tooth chisel as a middle-stage tool, is on the seventeenth drum of the column, i.e., almost at the top (fig. 11d). There two heads in not very good shape have an unfinished background. The area is at a stage that on a sarcophagus would still be point-chiseled, while on a Renaissance work it would be tooth-chiseled. In this case the background has been cut with a narrow, round-headed chisel. This bit of evidence is so small as to be inconclusive. It is still true, however, that the only extensive evidence of the use of toothed tools on both monuments is as a surface finishing tool.

The purpose of this review of the tooth chisel and its use has been to show that it is a tool that could be used in a variety of ways for different purposes by carvers in Rome and Aphrodisias. Its use can vary from place to place and from monument to monument. I have only barely suggested the complexity of its use, or even its nonuse in places where we would expect to find it. If this complexity exists, then we need clear and comprehensible documentation in order to make valid chronological comparisons. Because the ancient Greek tool, the ancient Roman tool, the medieval tool, and the modern tool all look very much alike, it has often been assumed that their uses have not changed. Until we have documentation that allows for accurate comparisons of tool marks, we are going to have trouble knowing just what these differences are.

Given this complexity, I doubt that it is possible to make a technically accurate fake of an ancient marble carving. Roman use of toothed tools is sufficiently different from modern use so that a faker would have to unlearn and relearn his whole use of tools, to say nothing of the rest of his sculptural technique. I once tried to use a tool the way it seemed the Romans used it. I learned an instructive lesson. I have always been a great admirer of the way Roman sculptors used the round-headed chisel, for they were able to carve so much and get such beautifully modulated surfaces with it. When I tried to reproduce that effect on one of my own sculptures, I found that to do it right I would have to change my way of working with the point and tooth chisels and find a blacksmith who would make me a slightly different round-headed chisel with a different temper in the steel. All these things might be possible, but from what I have seen of fakers, I doubt that they would do it.

In Robertson Davies's novel *What's Bred in the Bone*, the main character wants to be an artist but ends up training as a restorer by learning to reproduce old paintings perfectly. His masterwork is so exquisite that, without his intending it, it becomes known as an authentic, hitherto undiscovered masterpiece. There is a great deal more to this fascinating tale, but what interested me most was that this man found himself locked into the style of the masterwork. Having learned to paint perfectly as a sixteenth-century German, he could never again paint in any other way. I think this fiction fits reality.

My impression has been that good fakers usually take great pride in working in many different styles. On the other hand, to make a technically perfect fake requires retraining one's technique to fit the period, not an easy or short-term project. Therefore a good faker must create a bad fake. If the bad fake gets by us, it may well be due to our incomplete knowledge of the techniques of the period in question, not the technical perfection of the faker.

In reading literature on fakes and faking I find that no one questions that the faker can, if he wants to, reproduce the technique of the period being faked. It is taken as a given that a good technician can reproduce the technique of any period. I think that this is an assumption about techniques, based on the ignorance of nontechnicians, that deserves serious questioning.

The Decline and Fall of a Greek Portrait: A Fake Portrait Tells Its Story

Flemming Johansen

Museum visitors can look at Greek and Roman portraits only from a distance – a closer examination is not possible. Washing or cleaning a dubious portrait is usually impossible: One has to work with photographs or reproductions in books, and one's statements about a given portrait will often have little technical background. However, the situation is often better in the museum in which one works.

I have chosen as my topic a marble portrait in the Ny Carlsberg Glyptotek in Copenhagen. A head of almost natural size, 50 cm high, it portrays a serious, elderly bearded man, and carries the inscription ANTIΦΩN on the herm. The portrait (figs. 1a–e), inv. nos. 3560 + 3560A, was acquired by the Glyptotek on the art market in the autumn of 1975.

When the portrait was acquired, it was generally believed to represent Antifon, the Attic orator, lawyer, politician, and author (480–411 B.C.), who was one of the supporters of the oligarchic party in Athens during the Peloponnesian War. Two other famous ancient Antifons were the fifth-century sophist and interpreter of dreams and the mid-fourth-century tragic poet at the court of the Elder Dionysios of Syracuse.

No other portrait of Antifon is known, and no replicas of this portrait have as yet been found. Stylistically the portrait could be dated just after the death of Antifon the orator, but it also has stylistic connection with the portrait of Antisthenes (450–365 B.C.), which formerly was dated in the fourth century B.C., but which is now dated by Bernard Andreae in the first half of the second century B.C. To date our portrait as a Roman copy is difficult, but one could assume it was from Antonine times or later, from Severan times, circa A.D. 200 if it is compared to portraits of Septimius Severus.[1]

It is a well-preserved portrait: only the back of the head has been broken off, but it has been replaced. The man has a long beard and thick hair arranged in individual locks (figs. 1a–b). It is understandable that the Glyptotek was interested in an acquisition of this kind: a portrait in perfect condition, which seemed genuine, a unique piece of sculpture of high quality, and a completely new

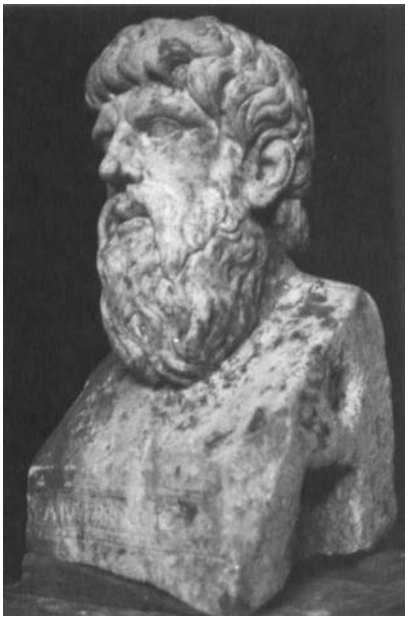


FIG. 1a.
"Antifon." Front. Copenhagen, Ny Carlsberg Glyptotek 3560 and 3560A. Photos: Ny Carlsberg Glyptotek.

FIG. 1b.
Back of head, figure 1a.

FIG. 1c.
Underside of head, figure 1a.

FIG. 1d.
Herm, figure 1a.

document to throw fresh light on the history of Greek portraiture. The portrait was offered to the museum in July 1975 and bought before the end of November of the same year.

The normal procedure in the Glyptotek is for a newly acquired marble portrait to be washed in water before it is put on display in the gallery. In 1975 our restorer, Aksel Theilman, was, at the age of seventy, very experienced, but unfortunately he had not been asked to give his expert opinion on the portrait before its acquisition. When the portrait of Antifon entered his workshop around Christmas 1975, Mr. Theilman set about carefully cleaning it of dirt and traces of earth. What looked like earth or dirt turned out, however, to be a very hard encrustation, which had to be removed as completely as possible in order to bring the surface below to light. The encrustation was very hard and in some places crystalline in character, and it was not always clear what was marble and what was encrustation. Only on the bottom of the herm was an old encrustation with rootmarks, which could not be removed.

During the mechanical work of cleaning away the encrustation, Mr. Theilman found a fissure in the neck, which until then had appeared unbroken – mainly thanks to the encrustation, which had covered the surface. After this discovery an X-ray of the head and neck was made, which showed a vertical metal dowel. Measurements on the neck above the fracture showed a larger diameter here than on the herm, and it became evident that the head had not originally belonged to the herm. One could, after this discovery, of course hope that the head and herm had been brought together in antiquity or during the Renaissance.

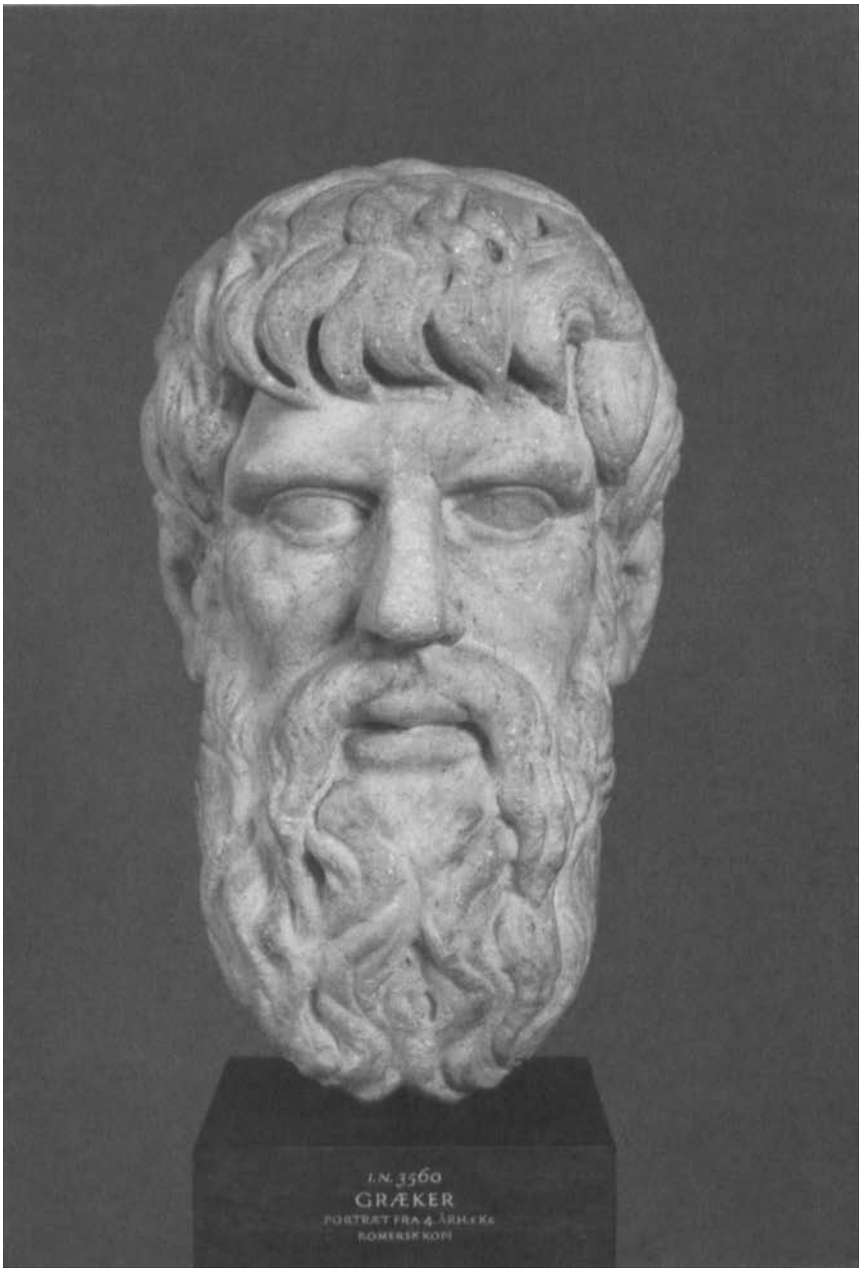


FIG. 1e.
Head, figure 1a.

An initial consultation with a geologist had indicated that the encrustation on the portrait was not silicate but more likely calcareous matter. Now the encrustation was analyzed by the Mineralogical Institute of the University of Copenhagen, which found that it consisted of calcite, ground marble, barium sulphate, color pigment, and a type of plastic glue that only entered the market during the last twenty to thirty years!

The marble is Greek, probably Parian. Stable isotope analysis of samples from head and herm show that the marbles of the two parts are not significantly different, considering the natural variation occurring in marbles from the same site as well as the latitude involved in petrological analysis.

		^{13}C ‰	^{18}O ‰
A	Bust or herm with inscription	+ 3.66	− 3.42
B	Head	+ 3.57	− 3.61

The tests are in a marginal Paros square in a ^{13}C-^{18}O plot.

The circular modern iron dowel was sawn through and the head separated from the herm. That revealed a marble tenon that was cut out under the neck; both the tenon and the area around it were white and looked very fresh (fig. 1c). By contrast, the square hole under the beard, which had not been filled in, had patina and looked older. The hole in the herm, which was cut out recently in order to join the head and neck, was filled with glue (fig. 1d). This glue also had plastic components, which indicate that head and herm were joined within the last twenty or thirty years.

It is possible to trace two stages in the history of the portrait. A portrait head of a bearded man was made from a block of Parian marble, which already had a square hole cut with a pointed chisel. The "flat" surface of the back of the head indicates the dimensions of the block before the portrait was carved. A tenon was cut in the neck with a flat chisel, not exactly in the center, for it had to be made where there was enough material, i.e., on the border of the old square hole. The head was given an artificial patina made with iron sulfate and was then joined with a herm, which carried the inscription *Antifon*. For this process the marble tenon was cut in the neck to join the hole in the herm. The join made the complete portrait quite shortnecked but not unnaturally so: it had raised no suspicion at the time of acquisition. Finally, the sculptor gave the whole portrait, both head and herm, a coat of encrustation.

The questions now are: Is the head ancient, is the herm ancient, and is the inscription ancient? The inscription is Greek, cut within a frame of triple lines. The ductus of the lettering is ancient and the inscription must therefore belong to the ancient herm. The herm has square holes at both sides for the now missing "arms." On the left side is a small hole with apparently ancient traces of lead. The conclusion must be that we do, after all, have an ancient herm with the inscription *Antifon*. It is, however, not possible to tell which one of the three famous Antifons has been named here.

We return to the head (fig. 1e). If we consider it ancient, we must call it a dull Roman copy of a Greek original from the second century B.C. The treatment of the beard and the hair on the forehead is a mixture of portraits of Epikouros and Homer

(Copenhagen). It is close to the treatment of the hair on the so-called Virgil in Copenhagen, which is now considered Hellenistic and not Roman. The dullness of the head, the peculiar hairstyle, the treatment of the beard, the dryness in the cutting, and the strange patina make me believe that the head is a modern portrait made within the last twenty years. To say so for certain is, however, not possible.

This is exactly the dilemma that many works of art present when they appear on the art market today, and we have the same problem with many so-called ancient sculptures that are already in museums all over the world. When one studies ancient art, one should give the question of fakes more attention. A fake work of art – a sculpture or a portrait – is after all a very interesting problem, for the fake can show a dimension of style that can be difficult to detect in a genuine ancient work. Who is the expert today? The classical archaeologist and the restorer who collects information and has a certain knowledge of ancient sculpture, as well as the forger who manufactures the fakes and is more dexterous than the archaeologist working in the museum. The forger will reach the same results or conclusions about details as the professionals, for their sources of information are the same. If the forger had not collected all available information, his works would never fool the scientists. Experts often forget that almost all knowledge, even the most specialized, can be acquired by everybody.

Much more study of genuine works of ancient sculpture from Hellenistic and Roman times is needed. Sheila Adam has studied the technique of Greek sculpture in the Archaic and Classical periods,[2] but the same kind of study is needed for the later periods, as are specific studies. How did the ancient sculptors cut an ear, a mouth, hair, eyes, etc.? Such a study, made with the help of computers and employing computer graphics, would be of great use to professional museum people – and to forgers.

Ny Carlsberg Glyptotek
COPENHAGEN

Notes

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Isotope Analysis of Greek, Roman, and Renaissance Marble Heads from the Antiquarium at Munich

Josef Riederer

In 1972 Craig and Craig[1] could demonstrate by a series of analyses of the $\delta^{13}C$ and $\delta^{18}O$ ratios of marbles from different Greek locations that this ratio varies with the provenance of the marble. During the following years the data on geological samples of marbles were enlarged considerably by the analyses of specimens from other regions, especially Turkey. This large data bank of isotope ratios from about twelve important types of marble induced the Rathgen Research Laboratory in Berlin together with the Geochemical Institute of the University of Göttingen to apply the knowledge to the analysis of a large series of marble heads,[2] which were at that time examined by archaeologists and art historians.[3] The heads are part of the collection in the residence of the dukes of Bavaria at Munich that was founded in the sixteenth century.

In the following article the results of the isotope analysis are briefly described, with more extensive remarks on the problems encountered in this study and the efforts that are necessary to overcome these problems.

During the Renaissance, Greek and Roman antiquities were highly appreciated, and many European dukes set up big collections of antiquities, which today form the nuclei of the antiquity museums in Europe. In the middle of the sixteenth century the Bavarian duke Albrecht V accumulated incredible quantities of antique objects, which he got from agents working for him in Greece and Italy. At the same time, large private collections consisting of many thousands of objects came into the residence of the Bavarian dukes at Munich. At the end of the sixteenth century a special building, the Antiquarium, was constructed in connection with the building complex of the residence to accommodate the collection of antiquities. A central part of this collection was a group of antique marble heads, which were arranged on the walls of the Antiquarium. During the following centuries the original collection, which comprised about 250 heads, increased by further acquisitions, although it was also reduced in times of war and political trouble. The 1987 catalogue of the collection mentions 386 objects. Among these are about 310 heads; the rest are torsos and fragments. The critical historical examination of the 310 heads led to the conclusion that about 150 are Greek and Roman, while 160 date from the Renaissance. The ancient material consists of Greek originals, Roman originals, and Roman copies of Greek sculptures. The objects from the Renaissance are originals, copies, or even intended forgeries of ancient heads. It was thus a project of considerable historical interest: comparing the archaeological information with the analytical data on the provenance of the marbles.

When the isotope study of the marbles of the Antiquarium was undertaken, there was already evidence from various directions that different types of marble could be distinguished by structural properties, by their microscopic data, and by chemical analysis. Though there was evidence on the difference of the microscopic properties of marbles from different origins already in the nineteenth century by Lepsius[4] and Washington,[5] more detailed microscopic study with modern analytical methods started no more than forty years ago. The microscopic studies undertaken until now, first of all by Marinos,[6] Liberti,[7] Herz,[8] Herz and Pritchett,[9] Weiss,[10] Bautsch and Kelch,[11] Renfew and Springer,[12] Turner,[13] and Germann et al.,[14] have restricted themselves to single objects, to special problems, or to an isolated group of marbles, so that a comprehensive overview even of the more important species is still missing.

In 1964 Rybach and Nissen[15] undertook a broad study on the contents of manganese and sodium in 230 samples from marble quarries in Greece and Turkey. They observed that especially the amounts of manganese, which varied from 0.5–200 ppm, provide an ideal possibility of distinguishing different types of marble.

Later Conforto et al.[16] extended this experiment by the emission spectrography and X-ray fluorescence analysis of 137 samples, again from various sites, with the result that, in spite of many overlappings of element concentrations, there is still a certain number of characteristic features that permit an identification of provenance.

Germann et al.[17] solved a special problem concerning marbles in northern Greece by covering also the chemical analysis, contributing by that to a further expansion of our knowledge on the variation of trace elements in marble. Lazzarini, Moschini, and Stievano[18] analyzed the Ca/Sr-ratio from sixty-two samples of marble from Italy, Greece, and Turkey, supporting the evidence that in spite of frequent overlappings, there are still some characteristic features for the certain identification of some types of marble.

Thermoluminescence studies on artificially irradiated marbles were undertaken by Aforkados, Alexopoulos, and Miliotis,[19] providing further evidence that marbles of different origin show different analytical properties. Cordischi, Monna, and Segre[20] examined 150 samples from 12 regions in Italy, Greece, and Turkey by ESR analysis, which led to the distinction between some of those groups with similar chemical or isotope data. Later Lloyd, Smith, and Haskell[21] built on this information with another series of ESR data from marbles.

In 1972 Craig and Craig[22] published their results on the isotope analysis of a big series of samples from the four most important types of Greek marbles, from Naxos, Paros, Pentelikon, and Hymettos. They demonstrated that the $\delta^{13}C/\delta^{18}O$ ratios of these four types of marble fall into five clearly separated fields, since the samples of Naxos consist of two different subspecies.

In the following years further publications by Manfra, Masi, and Turi,[23] Holzmann,[24] Coleman and Walker,[25] Germann, Holzmann, and Winkler,[26] and especially the recent extensive study of Herz in 1987,[27] have enlarged our knowledge on isotope data from other Greek marbles and from Anatolian samples. At the same time they have complicated the situation, since in some cases large overlapping areas of the fields of ratios make a clear distinction between marbles of different origins almost impossible. In spite of this experience, some positive applications of the isotope analysis were published in the following years by Herz and Wenner,[28] Reese,[29] Sangermano, Miller, and Bunker,[30] and Weisburd,[31] first of all to check if different pieces of one object originally belonged together.

In a first comprehensive study of a group of archaeological objects, the $\delta^{13}C$ and $\delta^{18}O$ values were determined on seventy-four of the heads of the Antiquarium in Munich. The aim was to get, for the first time, a broader range of data on the behavior of samples from ancient objects. (Up to this time, mainly geological samples from recent quarries had been analyzed.)[32]

Before going into the details of the analytical data, three results of this project should be mentioned. First, a large variety of isotope data was observed, proving that various types of marble had been used by sculptors in antiquity and during the Renaissance. Second, although there is no doubt about the accuracy of the analysis, the analytical data did not fit well into the fields determined by the analysis of geological samples. Third, of the seventy-four samples, fourteen could not be attributed with a high probability to one of the known provenances, and three could not be localized at all, since their data were too far from the already established isotope ratios.

Among the seventy-four samples from heads, twenty-two were identified as marble from Naxos, eight as marble from Pentelikon, eight as marble from Paros, eight as marble from Hymettos, and eleven as marble from Carrara. Among the fourteen uncertain attributions, it was difficult to distinguish between marbles from Naxos and Hymettos and between the marbles of Hymettos and Carrara, since there was a certain number of objects between the two fields of earlier established rations.

If we now consider the reliability of the attribution of the measured isotope data to the fields of isotope ratios for the different types of marbles elaborated earlier, we find that one of the two types of marble from Naxos encountered by Craig and Craig,[33] which is characterized by the lowest $\delta^{18}O$ values, below -8.5, does not occur among the ancient objects. So this may be a modern quarry, which was not used in antiquity. The attribution of the samples with the lowest $\delta^{18}O$ values to the marble from Pentelikon seems to be quite correct, since this type does not interfere with any other type of marble.

The problems of deducing the provenance of the marble from its isotope data become obvious with the data between -4 and -7 for $\delta^{18}O$ and $+2$ and $+3$ for $\delta^{13}C$. In this region the marble of Naxos overlaps with the marbles from Ephesos and Kastrion. Besides, the third Anatolian marble from Atrax resembles them quite closely in its isotope data. Because of criteria of the marbles' fabric, grain size, and microscopic features, together with the archaeological evidence, these samples were declared marbles from Naxos, but in some cases, especially those with $\delta^{13}C$ values over $+3$, there remains a considerable uncertainty about the reliability of this statement.

The marbles of Paros, which are characterized by high $\delta^{13}C$ values, can be identified with a greater probability, since only one type of marble, from Ephesos, crosses their field, but as with one of the types of marble from Naxos, there is no evidence that this type was used in antiquity.

With the marble of Hymettos there is the same difficulty as with the marble of Naxos, namely that it overlaps completely with two Anatolian marbles, those of Gonnos and Tempi, and it closely resembles three other Anatolian marbles, from Ephesos, Afyon, and Aphrodisias. Again, the macroscopic criteria and microscopic features are weak arguments that all samples ascribed to Hymettos are in fact from that quarry.

Finally, marble from Carrara was identified as the material of some of the heads from the Antiquarium. Though this type is quite close to the marble of Hymettos and some Anatolian groups, the fine-grained structure distinguishes Carrara with great certainty. The samples from Carrara are all characterized by extremely high $\delta^{18}O$ values of -1.0 to 1.7.

It is thus obvious that in many cases isotope data alone are not completely reliable for determining the geological origin of a marble, so other types of analysis have to be considered.

Examination of the heads by archaeologists and historians combined with the isotope analysis allows some interesting historical conclusions. Eleven of the seventy-four heads that were analyzed are Greek originals from the Classical period. Eight of these are of Naxian marble, two of Parian, and one of Hymettian. That clearly indicates that during the Classical period, Cycladic marbles, and primarily the marble from Naxos, was the preferred material, while local marbles of the mainland were not used as much.

Interpretation of the results of the analysis of heads from the Roman period is almost impossible, since only some of them were made in Italy, either from local marble, from imported stone, or from reworked Greek heads. A large quantity of the Roman heads preserved at the Antiquarium are copies produced in Athens and other Greek cities after Greek originals, and on the western coast of Turkey there was an extensive production of Roman sculptures. It is therefore not surprising that among the Roman heads we find ten examples that are made of marble from Naxos and three from Paros, as well as six heads of marble from Hymettos and four of marble from Pentelikon, indicating that these local types increased in importance during antiquity. Finally, Ephesos occurs with two objects, and two heads are of marble from Carrara.

During the Renaissance, marble of Carrara predominated. It was used in Rome and Florence and since the sixteenth century also in southern Germany, where the Bavarian dukes had rounded out their collection with modern copies. Besides the marble of Carrara, Greek marbles were used extensively, particularly the marbles of Naxos and Paros, but also marble from Pentelikon and Hymettos. With respect to the Greek marbles, it is possible that ancient originals were completely reworked in the sixteenth century in Italy. It is remarkable that objects that can be recognized as produced in upper Italy primarily consist of Greek marbles.

The present situation concerning the possibility of localizing marble by means of analytical data is characterized first by the fact that a large quantity of microscopic, chemical, and isotopic data has already been developed, showing a wide variety of properties, which encourages further efforts to connect the analytical data to the provenance of the marbles. The second observation, which opposes a general application of these data for the solution of archaeological problems, is the fact that little systematic research has been done on the analytical properties of marbles. Third, there has been relatively extensive research on geological material, but almost no application of it to the resolution of archaeological problems, to which the geological data may not be readily applicable anyway. To overcome these difficulties, the following steps must be taken:

a. All marble deposits in Italy, Greece, and Turkey, and eventually also in other regions where marble was quarried in earlier periods, must be analyzed in detail.

b. This geological evidence should be compared with information in the historical literature, since today there is little evidence from antiquity about the importance of the different marble deposits.

c. A representative collection of marbles should be brought together with a view to determining their microscopic properties, chemical composition, and isotopic characteristics, and to apply other techniques that hold out the promise of distinguishing marbles of different origins.

d. A representative number of archaeological and historical objects with relatively reliable provenance should be similarly analyzed with the aim of comparing the data and in order to check whether the burial of a marble object for millennia alters isotope ratios or other properties on its surface.

A systematic and comprehensive examination of a well-considered selection of samples and objects would provide the basis for reliable information of high historical importance, established by scientific analysis.

Rathgen-Forschungslabor
BERLIN

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Rosso Antico and Other Red Marbles Used in Antiquity: A Characterization Study

Lorenzo Lazzarini

All red crystalline marbles used in antiquity have traditionally been identified by archaeologists as *marmor Taenarium*, the marble from Cape Tainaron, the present-day Matapan (Greece). This marble is better known by the Italian name of *marmo rosso antico*, probably given to it in the last century by the Roman stonecutters responsible for most of the names of ancient marbles that are still used today.

Important works of art have been created with this marble, from the Minoan and Mycenaean through the Neoclassical period. Lamps and small vases, some in the form of a rhyton, have been found in various localities on the island of Crete. Blocks with spirals and rosettes carved in relief decorated the portal of the so-called Treasury of Atreus in Mycenae (1350–1250 B.C.) and are now kept in the British Museum, the National Archaeological Museum of Athens, and the Museum of East Berlin (fig. 1).[1]

Marmo rosso antico was used in the Peloponnesos in the Classical and Hellenistic ages for small stelai dedicated to the Spartan cult of Artemis Orthia. But the apex of its use was during Roman Imperial times when, because of its color, this marble was considered one of the most precious stones. Like *porfido rosso antico* (Egyptian porphyry) it is purple, the same color as that used in the cloth of the nobility, the rich and powerful, and, more especially, of the emperors.

Marmor Taenarium of uniform color and fabric was available only in relatively small blocks. These were carefully selected and used for beautiful and important sculptures such as the Drunken Faun in the Museo Capitolino in Rome, a copy from Hadrian's time of a now lost Hellenistic original (fig. 2). Another Roman faun is in the Vatican Museum, while other important examples of *rosso antico* statues are the Centaurs in Galleria Doria, Rome, and in the Getty Museum, the latter once in Domitian's palace at Castelgandolfo. A beautiful bust of an Isiac priest is in the Grimani Collection in the National Archaeological Museum in Venice, and a statue, like the Drunken Faun from Hadrian's time, is in the Egyptian Museum in Munich. Absolutely exceptional are two ancient Roman toilet

FIG. 1

Relief of *rosso antico* from the entrance of the Treasury of Atreus, Mycenae. London, British Museum. Photo: author.

chairs later used for ceremonial purposes by the popes, now in the Vatican Museum.

More common are small sculptures, stelai, and reliefs, which became quite popular, not only in Rome (see, e.g., the young Bacchus in Galleria Doria; the two hydrophorai in the Museo Barracco; the comic mask in Villa Albani; and the herm of a faun and the head of a goat in the Vatican Museum) but also in the provinces of the Empire. Among provincial examples are a small herm of a faun in the Museo Civico in Padua (once more testifying to the use of *rosso antico* for Dionysiac cult statues: the stone is wine-colored), a beautiful tondo with Odysseus and the Sirens in the Archaeological Museum in Urbino, and a stele in the National Archaeological Museum in Altino (Venice). *Rosso antico* was also used for trapezophori and vases and for small tubs, sometimes figured, like the one in the National Archaeological Museum in Naples.

The predominant use of this marble, including the white-striped variety, was, however, for architectural elements, usually of small size. A notable exception is the fragments of large cornices now in the Gallerie del Cortile Ottagono in the Vatican. But more frequent were little cornices (fig. 3) at the base of walls (as in a building of the ancient Alaisa, Sicily), which are found in many Roman towns, including some of secondary importance, such as Vicenza (Municipal Museum), Padua, Ercolano, and Pompei. *Rosso antico* was also extensively used in slabs for facing walls and pavements, and in blocks for small capitals and bases.

A more precious use of this stone is for marquetry, as in Domus Flavia in Rome, and in *opus sectile* (see, e.g., that of Piazza d'Oro in Hadrian's Villa in Tivoli, where lozenges of our marble are combined with red and green porphyries, *Palombino*, and a black slate), often of complicated patterns, and as mosaic *tesserae* (see, e.g., two mosaics in the museum in Sparta and one in the Museo Civico in Padua).

According to Raniero Gnoli,[2] the use of *marmo rosso antico* began in Rome at the end of the Republic or at the

FIG. 2

Drunken Faun, second century A.D. Rome, Museo Capitolino. Photo: author.

very beginning of the Empire, as testified by the pavement under the Ludus Magnus. Because of its symbolic color, equivalent to that of the porphyry, the mythological association with the Tainarian Poseidon, the entrance of the Kingdom of the Dead, and with the cult of Bacchus, it soon became one of the most precious and appreciated stones. It is specifically mentioned by the Roman writers Tibullus (III.3.13) and Propertius (III.2). We do not know whether *rosso antico* quarries were Imperial property but there is evidence that only small quantities were quarried. In spite of this, and against the opinion of Gnoli, its use, mostly for small decorative elements, spread throughout the Roman Mediterranean.

FIG. 3
Small cornices, probably *rosso antico*, of various shapes and provenance. Photo: author.

The height of *rosso antico* appreciation seems to have been during the second century A.D., especially under Hadrian when, as testified above, many statues were carved in this stone. Probably toward the end of the third century the search for red marbles grew considerably, and a new stone, the Carian marble (also called Iassense by the Romans, or *cipollino rosso* and *Africanone* by stonecutters), was introduced in Rome and became very popular in Byzantine times.

Marmo rosso antico probably continued to be exploited in late antiquity, and we find it in Byzantine monuments, not only in the most famous ones of Constantinople and Ephesos but also in other provinces of the Empire and in Athens (witness the two fragments of small columns in the Byzantine Museum there) and Thessalonika. In Byzantine times there was also reworking and reuse of *rosso antico*.

The largest reuse, however, occurred in the late Middle Ages and the Renaissance, especially in Rome, where we have important examples in both churches (see, e.g., the fourteen large steps of the main altar of San Prassede) and palaces (see the two beautiful columns of the Casino dell'Aurora of Palazzo Rospigliosi-Pallavicini, fig. 4).

In the Baroque period *rosso antico* was used extensively for funerary inscriptions and monuments; in Rome there is not an important church where it cannot be seen. In the eighteenth century it is reported again as one of the most costly and rarest of stones, much sought after in the Neoclassical period for the manufacture of small objects such as models of ancient temples and monuments, vases, candlesticks, etc.

Marmo rosso antico is a fine-grained true crystalline marble of rather uniform color that varies from dark red-violet to a deep red (fig. 5). It sometimes shows white stains or stripes and bands, the latter always plain, and a foliation marked by very fine dark brown-black veins, often very numerous, even if not very visible to the naked eye. The darker variety, and even more so the white-banded one, are very similar to the also fine-grained crystalline Carian marble, from which it can hardly be distinguished (fig. 6). Carian marble of uniform color and fabric, with plain white bands instead of the more common undulating ones underlining a plain schistosity, resembles

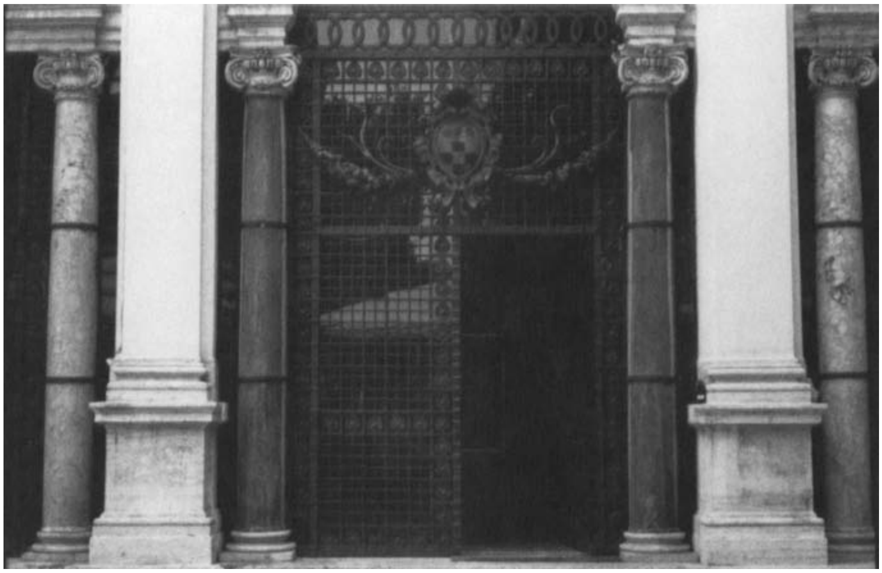


FIG. 4
Two columns of the white-banded variety of *rosso antico* at the entrance of the Casino dell'Aurora, Palazzo Rospigliosi-Pallavicini, Rome. Photo: author.

rosso antico particularly closely.

Very recently clear evidence of ancient quarrying in Aphrodisias (Caria, Turkey) indicates that a third red crystalline marble was probably used in antiquity, although in small quantities. This marble is of uniform bloodred color and shows a slightly larger grain size than the two previous ones (fig. 7).

Given the considerable macroscopic similarities of these marbles, it is very probable that too many works of art have been attributed to *marmo rosso antico*. Hence the necessity to be able positively to identify each of them by means of scientific analyses.

It is for this reason that a thorough sampling and detailed investigation of *marmo rosso antico* has been done, together with a parallel study of a few samples of the two other red marbles, from Iasos and Aphrodisias.

THE *ROSSO ANTICO*: GEOLOGICAL OUTLINES, QUARRIES, AND SAMPLING

The *rosso antico* outcrops on the Mani peninsula, the central finger of Peloponnesos, a region well mapped recently by the Institute of Geology and Mineral Exploration of Greece (IGME).[3] Mani is predominantly rich in mostly gray-colored crystalline marbles, but there are also some pure white crystalline marbles that were frequently used in antiquity, for example in the friezes of the temple of Bassae.[4]

All the Mani marbles belong to the Ks-Es.k formation of the Upper Senonian–Upper Eocene, defined in the IGME map as "Limestones: grey, greyish-white, crystalline, mainly platy or medium-bedded. Transition to marbles, often coloured (reddish, yellowish, greenish) in the upper parts," whose total thickness has been estimated to be 300 m.

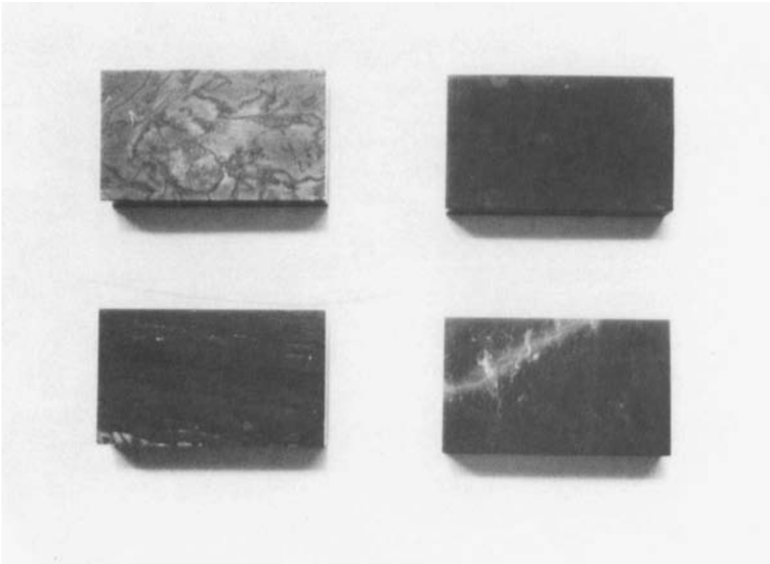


FIG. 5

Four specimens of *rosso antico* in the T. Belli Collection of ancient stones. Rome, Geological Museum, University "La Sapienza." Photo: author.

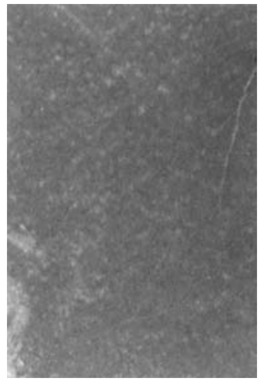


FIG. 6

Carian marble from the quarries near Iasos. Photo: author.

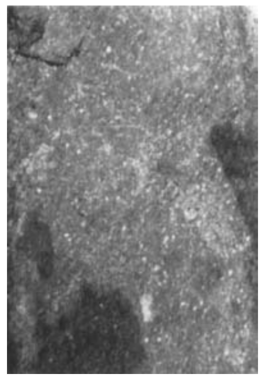


FIG. 7

Red marble of Aphrodisias from an ancient Roman quarry. Photo: author.

The red marble outcrops are small and not marked on the IGME map. They are quite difficult to find due to the steep orography of the area and the lack of roads, which makes traveling problematic. Those seen and sampled in this study are from north to south: near Platsa; on the Paganea and Kalivia promontories; near the abandoned village of Profitis Elias; and at the entrance of the Gulf of Marmaro (fig. 8). They lie approximately at the center of a large syncline including the Taigetos and Parnonos, their beds showing a strong inclination in the northern areas, a lesser one in the southern localities. No outcrops or quarries are present at the very end of the peninsula, Cape Tainaron, where remains of the Temple of Poseidon are still to be seen.

Evidence of quarrying has been found only at Paganea and at Profitis Elias. In the former spot a modern quarry was opened before World War II and the extracted blocks were shipped to England. It is very likely that this work has destroyed traces of ancient exploitation, as has intense karstic erosion, which most likely has obliterated cutting marks, etc., from the very surfaces of the outcrops.

At Profitis Elias there is evidence of several ancient quarries, some of which appear undisturbed by recent extraction activity. The maximum thickness of the *rosso antico* there can be estimated to be 50–60 m, but the largest quarry has a height of only 8–9 m and a front ten times larger. The quarry that has been most accurately sampled faces the sea on the southern slope of the small valley before one arrives at the village, halfway up the hill from the track (fig. 9a). It shows clear cuttings (fig. 9b) from ancient extraction with a pick, and right angles and channelings from the exploitation, as well as abandoned squared blocks. The length of the quarry is 50–60 m, and the height 7–8 m. It produced *rosso antico* of the white-banded variety.

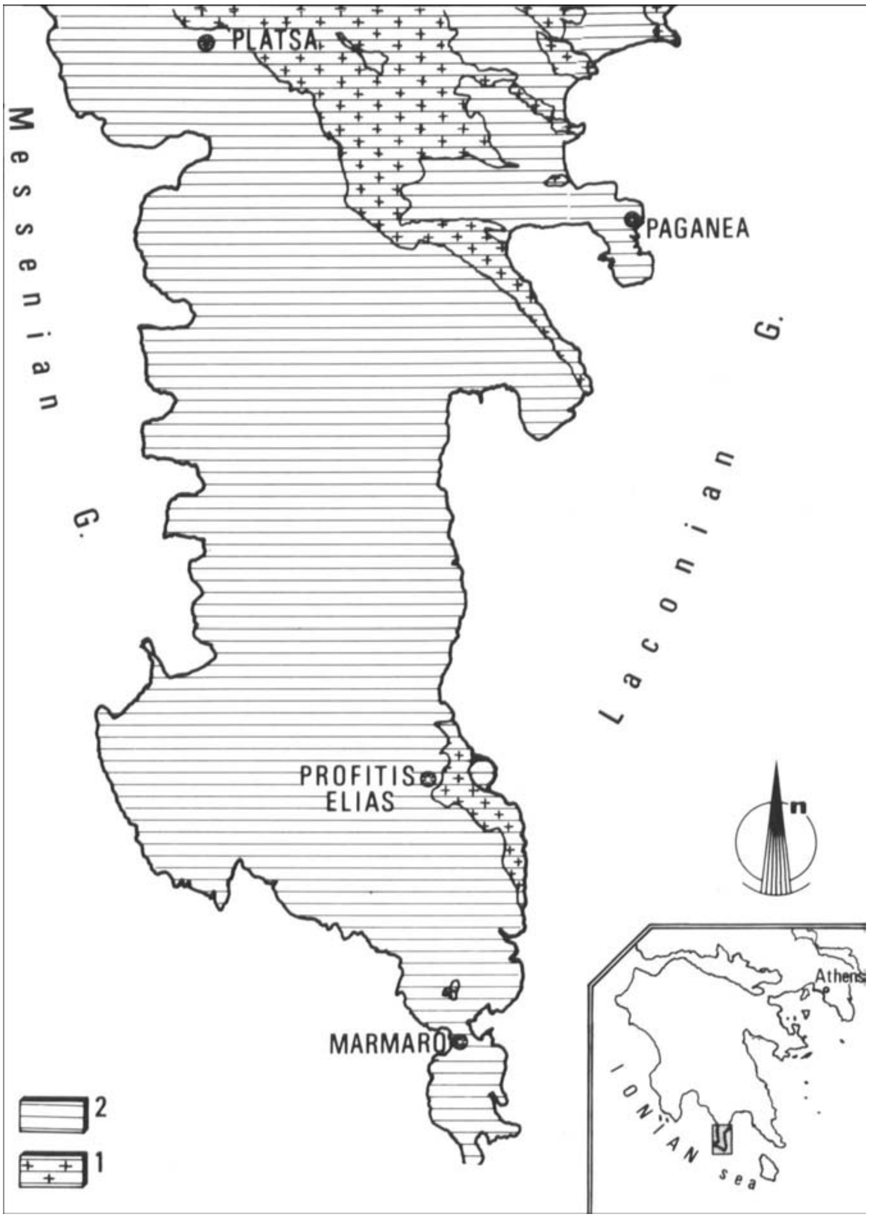


FIG. 8

Geological map of the Mani peninsula showing the sampling localities of *rosso antico*. 1 = Permian schists and phyllites and Triassic/Liassic limestones; 2 = Gray, grayish-white limestones and marbles, red marbles.

QUARRIES AND SAMPLING OF CARIAN AND APHRODISIAN RED MARBLES

The exact location of the quarries of Carian marble is not known. Judging from the great amount of this marble used in ancient monuments, they would have been very large. At least some of the quarries of this marble, used in much larger quantity than *rosso antico*,[5] are located approximately ten km from the village of Aşin Kurin (Milas), the ancient Iasos. Those quarries that are known are near the road and near the locality called Akbuk. They are mostly of small to average size (fig. 10); some of them are filled up with earth, but still show cutting marks and holes for the emplacement of wedges. In the large area near the road where many small extraction sites have been noticed, one can

FIG. 9a

One of the largest ancient quarries of *rosso antico* at Profitis Elias. Photo: author.

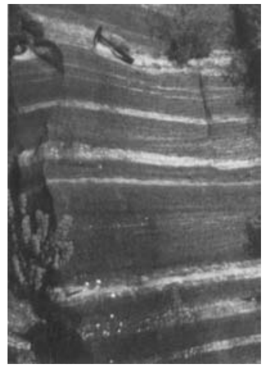


FIG. 9b

Detail of quarry front, figure 9a, with cutting marks. Photo: author.

also see an ancient square, which must have been used as a deposit for cut blocks, some of which, abandoned on the site in antiquity, were still there in 1983. Many others were removed in recent times and used locally for building modern houses.

The variety of Carian marbles extracted in the small quarries and sampled for this study is of a homogeneous dark red color, sometimes with plain or slightly undulating white bands (fig. 11), very similar to the *rosso antico* of the quarry described above.

The Aphrodisian red marble studied here has been sampled in one of the largest quarries, situated approximately two km west of the ancient city.[6] The red lithotype is interbedded with grayish and black marbles and is not very thick, so that only small statues could have been cut from it.

EXPERIMENTAL PROCEDURES

All the samples were thin-sectioned for microscopic examination under polarized light and analyzed by X-ray diffraction (Seifert Mz II, rad Cu Kα at 20 mA, 40 KV). The insoluble residues of some samples were gravimetrically determined by dissolving 0.5 g of the samples in fifty cc of a two-percent solution of hydrochloric acid. They were then submitted to X-ray diffraction for identification of the silicatic minerals and of the coloring ores. These have also been studied by optical microscopy in reflected light on opaque polished sections, as well as with an energy-dispersive X-ray microprobe (EDAX).

The quantitative chemical analysis of the samples has been carried out by X-ray fluorescence with a spectrometer (Philips PW 1400, with an Sc tube at 40 nA, 50 KV) on compresses obtained by mixing two g of sample with two g of wax and pressing it with a weight of fifteen tons. The data have been compared with those

FIG. 10

Small quarrying site of Carian marble near the road from Milas ten km before Aşin Kurin, showing holes for the emplacement of wedges. Photo: author.

obtained from standards of limestones (BCS-CRM number 393, D01-1) of the Institut de Recherches de la Sidérurgie, France, and with those resulting from the traditional wet analysis of our sample number 175.

All the samples, before their XRF analysis, were submitted to a rapid semiquantitative analysis by emission spectrography (Hilger Analytical EA 955) to check the presence of some forty elements.

RESULTS AND DISCUSSION

The *rosso antico* has proven to be quite a homogeneous low-metamorphic marble from the point of view of its mineralogical and petrographic characteristics. The samples from the four localities examined – Platsa, Paganea, Profitis Elias, and Marmaro – have, in fact, shown a very similar crystalloblastic, homeoblastic fabric, sometimes showing a local lepidoblastic schistosity in connection with K-mica and chlorite trains or concentrations. A clear layering is always evident in sections parallel to schistosity, often giving place to a dimensional preferred orientation produced by syntectonic crystallization of small equidimensional calcite crystals. Also frequent are areas of microcrystalline calcite as well as of calcite with larger grain size (fig. 12). Schistosity is also emphasized by haematitic veins frequently isoparallel to each other (fig. 13) and connected to quartz and plagioclase crystals.

The mineralogical composition is usually as follows:

- Calcite is the essential mineral and shows curved to embayed boundaries
- Quartz is quite abundant in subangular/

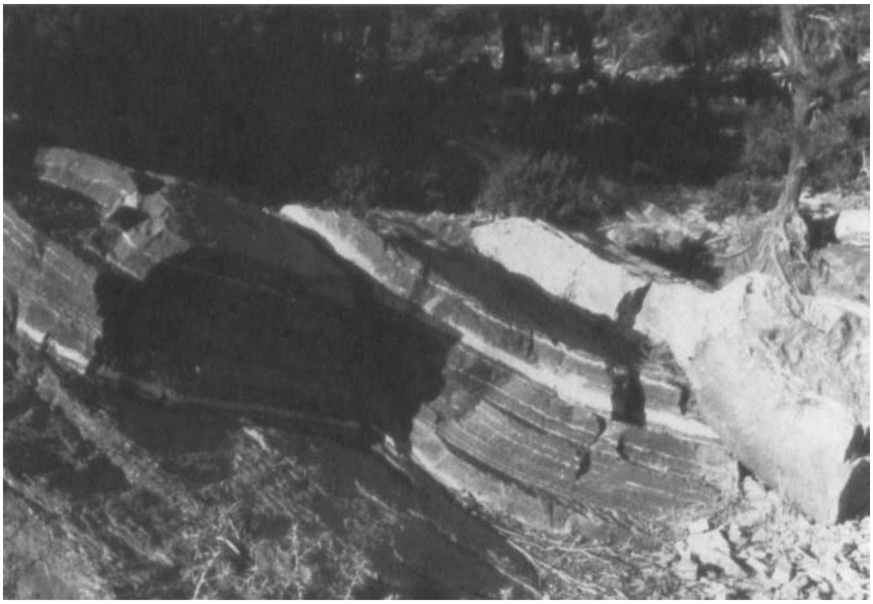


FIG. 11

Outcrop of the typical white-banded Carian marble at Akbuk with a clear undulated schistosity. Photo: author.

subrounded crystals, but also in polycrystalline individuals; sometimes it shows calcite and other inclusions and undulated extinction

- Plagioclase, often twinned with the albitic and albitic-Karlsbad laws, has an albitic composition
- K-mica, in tiny needles with high birefringence colors
- Chlorite, also in tiny needles and associated with mica, often forms veins with a feltlike structure
- Haematite, mostly concentrated in veins, but also dispersed in the mass of the rock as a dark red-brownish powder
- Epidote and limonite are sometimes present as accessory minerals

When present the white bands usually show a granoblastic heteroblastic fabric and are characterized by a larger grain size and a higher purity, typical of true marbles.

The Carian marble has a mineralogical composition and a fabric very similar to that of *rosso antico*, but exhibits a more marked preferred orientation and layering (fig. 14).

Other notable differences are visible in calcite, which often shows weak distortions in polysynthetic twinned crystals, and in plagioclases twinned with the albite law only.

The red marble from Aphrodisias shows a granoblastic homeoblastic polygonal fabric characterized by triple

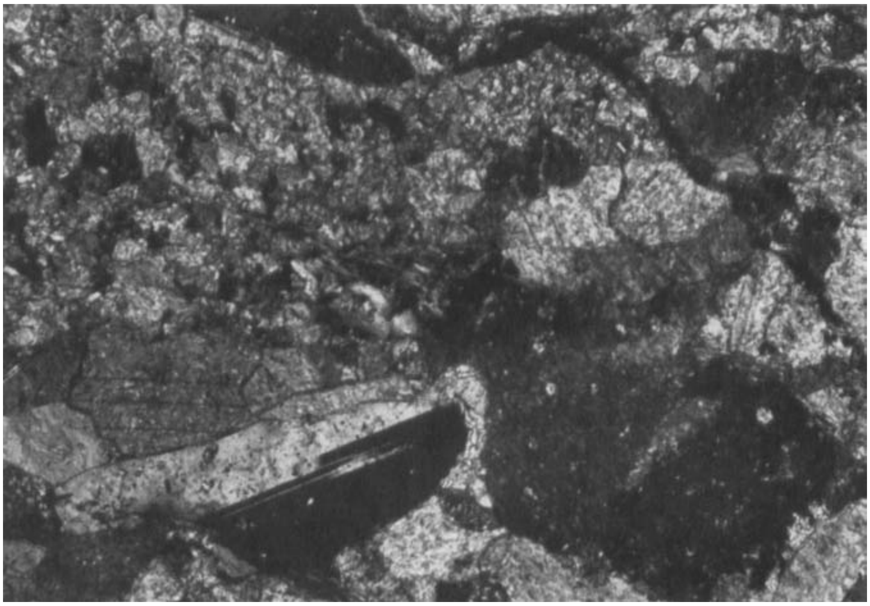


FIG. 12

Thin section of *rosso antico* showing a variation of grain size in calcite crystals and a twinned plagioclase. Photomicrograph. N +, magnification 130×. Photo: author.

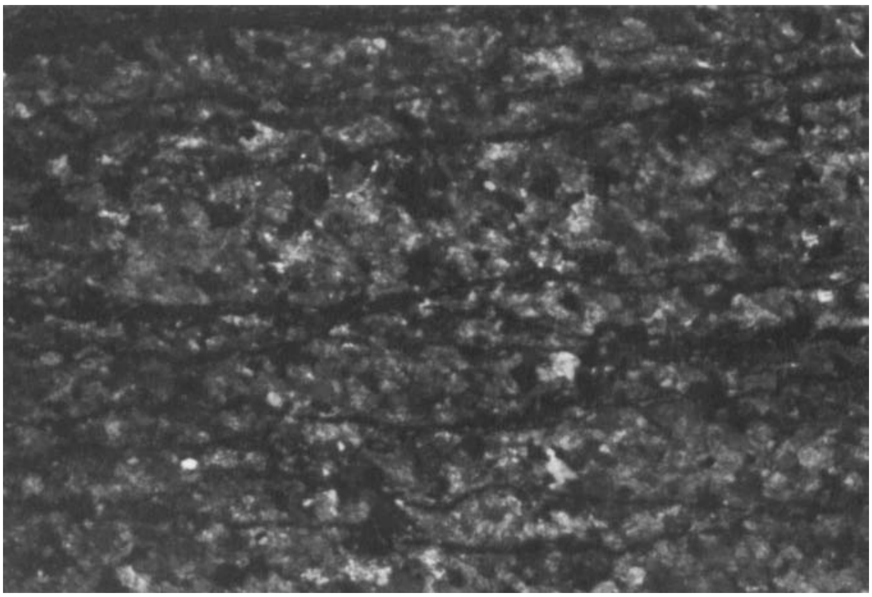
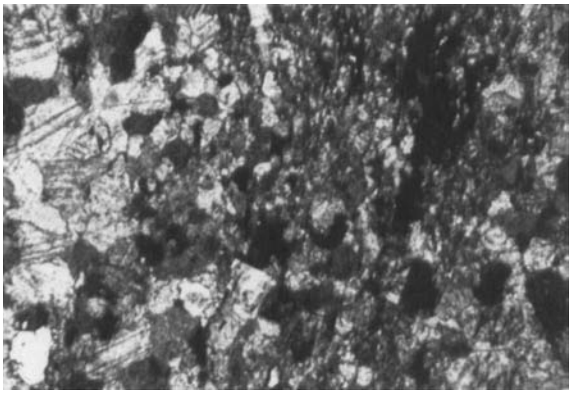


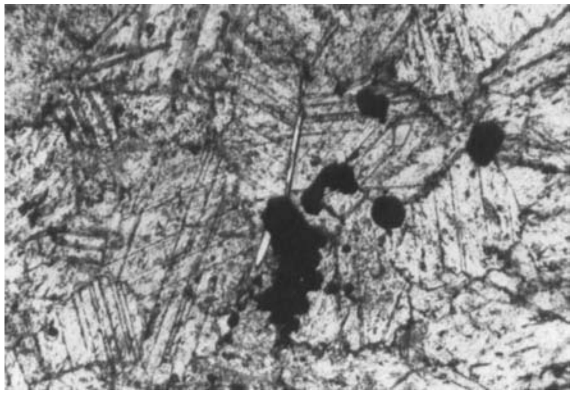
FIG. 13

Thin section of *rosso antico* showing a layered fabric underlined by dark brown haematitic concentrations. Photomicrograph. N +, magnification 85×. Photo: author.

points in calcite crystals (figs. 15, 16). The mineralogical composition is quite different from the previous lithotypes: chlorite and plagioclase are missing and

- Calcite shows straight to curved boundaries and often embeds particles of haematite, which are sometimes oriented according to cleavage and twinning planes
- K-mica is present in isolated needles or in trains and also has haematitic impregnations
- Quartz shows isolated subrounded crystals as





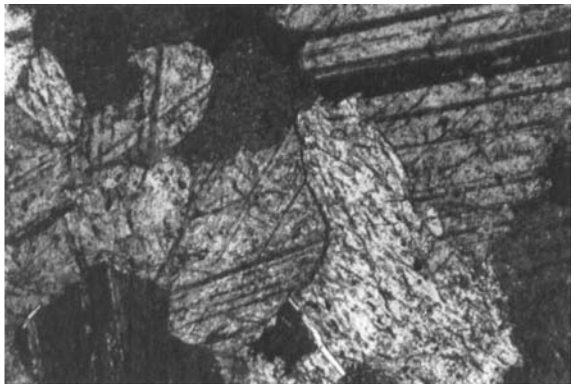


FIG. 14

Thin section of Carian marble showing an oriented fabric of heteroblastic calcite and quartz crystals. Photomicrograph. N+, magnification 55×. Photo: author.

FIG. 15

Thin section of Aphrodisias red marble showing a polygonal fabric, mica needles, haematitic opaque masses, and transparent inter- and intracrystalline impregnations. Photomicrograph. N//, magnification 55×. Photo: author.

FIG. 16

Thin section of Aphrodisias red marble showing the same features as figure 15, but N+. Photomicrograph. Photo: author.

FIG. 17

Polished section of *rosso antico* showing haematitic concentrations. Photomicrograph in reflected light. Magnification 90×. Photo: author.

well as polycrystalline individuals

- K-feldspar is in small subrounded crystals
- Haematite is very abundant in subtransparent resinous brown-red particles or in opaque ones

The X-ray diffraction analyses have confirmed the minero-petrographic ones and have allowed semiquantitative estimations of the minerals other than calcite (see Table 1), but they have proven of little utility in the differentiation of the three marbles: only sample number 177 from Aphrodisias appears distinguishable, showing the presence of K-feldspar and the absence of chlorite. The insoluble residues (see Table 2) likewise show similar results for the three marbles. A considerable difference has been found between the red and white parts of *rosso antico*, the latter being very pure and comparable to a true white marble.

In all residues of the red samples haematite was revealed by XRD, confirming that it is responsible for the red color of the marbles. The violet hue, sometimes quite evident macroscopically in the *rosso antico*, is certainly due to small amounts of Mn, which on the microprobe appear to be connected to the haematitic particles (fig. 17).

The preliminary spectrographic analysis of all the samples showed that in addition to the presence of the usual main

Table 1. XRD semiquantitative analyses of red marbles

Sample from	Sample number	Quartz	Plagioclase	K Feldspar	K Mica	Chlorite
Platsa	139	+ +	+			+
Paganea	1	+ + +	+		+	+
Paganea	3	+ +				+
Paganea	6	+			+	+
Marmaro	4	+	+ + +		+	±
Profitis Elias	9	+ + +			+ + +	+
Profitis Elias	10	+ + +	+		+ +	+
Profitis Elias	12 red	+ +	+		+ +	+
Profitis Elias	12 white	+ +			+	+
Iasos	175	+ + +	+		+ +	+ +
Aphrodisias	177	+ +		+ +	+ + +	

components of rocks (of which the notable absence of P was proven), only Sr, Ba, and Cu were present in detectable amounts for XRF, Ni and Cr being at the very limit of measurement.

Table 3 shows the results obtained from the quantitative analyses. Even at first sight the considerable homogeneity of the data for all the analyzed samples is evident. The *rosso antico* shows Ca percentages varying from forty-six to fifty-four, corresponding to different degrees of purity, and appreciable variations in silica and alumina in the samples from different localities, due to varying quartz and silicate contents, while minor variations are to be seen in the other elements. There seems to be a certain correlation between Fe and Ti, and it should be noted that Sr is absent from sample number nine, and Ba from samples numbers four and twelve (white area), the latter also showing a high calcium content with small amounts of Si, Al, Fe, K, and Ti.

The Carian marble from Iasos is not distinguishable from *rosso antico* on the basis of its essential chemical composition, but the red from Aphrodisias shows a very low amount of Mn and absence of Sr and Ba.

CONCLUSIONS

Rosso antico, Carian marble, and the red of Aphrodisias are to be considered true marbles with various degrees of "impurities" in the form of quartz, feldspars, K-mica, chlorite, and haematite.

The red-violet color of *rosso antico* and Carian marble is due to haematite containing small quantities of Mn, while the red color of the Aphrodisian marble is mostly due to haematite.

Table 2. Insoluble residues of red marbles

Sample from	Sample number	% (weight)
Platsa	139	9.38
Paganea	1	12.13
Marmaro	4	9.15
Profitis Elias	12 red	11.82
Profitis Elias	12 white	1.32
Iasos	175	10.00
Aphrodisias	177	7.84

Table 3. Chemical quantitative analyses (% weight) of red marbles

Sample from	Sample number	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	SrO	BaO	CuO
Platsa	139	7.40	0.92	0.42	0.90	51.80	0.27	0.14	0.043	0.095	0.08	0.15	<0.01
Paganea	1	14.80	2.90	1.04	1.03	48.90	0.25	0.44	0.085	0.197	0.05	0.04	<0.01
Paganea	3	4.71	0.96	0.46	0.77	53.70	0.26	0.14	0.036	0.122	0.08	0.04	<0.01
Marmaro	4	7.46	1.49	0.64	0.87	50.35	0.24	0.26	0.063	0.285	0.06	—	0.019
Profitis Elias	9	11.44	2.42	0.84	0.98	50.81	0.27	0.44	0.073	0.224	—	0.02	<0.01
Profitis Elias	10	7.91	1.63	0.68	0.88	49.05	0.26	0.28	0.065	0.228	0.06	0.05	<0.01
Profitis Elias	12 red	8.73	2.04	0.84	0.84	46.40	0.23	0.36	0.082	0.199	0.07	—	0.042
Profitis Elias	12 white	2.13	0.33	0.05	0.85	54.20	0.32	0.02	0.003	0.130	0.07	0.15	0.018
Iasos	175	5.40	1.12	0.86	0.81	50.70	0.26	0.20	0.046	0.200	0.04	—	<0.01
Aphrodisias	177	4.11	2.30	1.13	0.66	54.00	0.28	0.23	0.092	0.038	—	—	<0.01

The mineralogical analysis is not of great help in distinguishing between the three lithotypes; petrographic examination, however, allows a certain differentiation between, on the one hand, *rosso antico* and Carian marble (the latter characterized by a more marked dynamic metamorphism), and, on the other hand, the Aphrodisian red marble, a marble with a higher purity and an equilibrium fabric.

Chemical quantitative analysis of the principal elements as well as of some minor and trace elements has not proven effective in the differentiation of the three red marbles used in antiquity, thus suggesting that the problem of fingerprinting for these materials has to be faced in the same way as for pure marbles.

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Notes

This work has been funded partially by the C.N.R. (the Italian National Council for Research) and partially by a grant from W. Dickerman, Boston. Thanks are also due to G. Kokkinakis, geologist of IGME (Tripolis, Greece), and M. Mariottini, geologist of ICR, Rome, for their assistance with the fieldwork, and to S. Spector Canal for reviewing the English text.

1 S. E. Ellis, R. A. Higgins, and R. Hope Simpson, "The Facade of the Treasury of Atreus at Mycenae, *BSA* 63 (1968), pp. 331–336.

2 R. Gnoli, *Marmora Romana* (Rome, 1971), p. 160.

3 IGME, *Mavrovoynion-Areopolis-Yerolimin Sheet*, 1984.

4 F. A. Cooper, "A Source of Ancient Marble in the Southern Peloponnesos," *AJA* 85 (1981), pp. 190–191; N. Herz, F. A. Cooper, and D. B. Wenner, "The Mani Quarries: Marble Source for the Bassai Temple in the Peloponnesos," *AJA* 86 (1982), p. 270. On the red and black marbles of Mani, see also: J. E. Papageorgakis, "Die in der Marmorindustrie nutzbaren Gesteine Griechenlands," *Annales géologiques des pays helléniques* 18 (1967), pp. 234–237.

5 Gnoli (note 2), p. 210.

6 The sample was taken by Peter Rockwell and kindly given to the present writer for analysis.

Once Again on *Marmor Luculleum*

Angelina Dworakowska

The term *marmor Luculleum* is first encountered in Pliny's *Naturalis Historia*, and the search for an answer to the problem of where this marble came from goes back to the beginnings of modern criticism of the text of this author. The confused readings of the most important parts of Pliny's text have compelled editors to choose among the geographical names proposed in the various manuscripts. Modern scholars[1] generally accept the theory that *marmor Luculleum* came from Teos. However, not all aspects of the source of *marmor Luculleum* have been considered and hence not all doubts about its origin have been removed.

When writing about the first marble that was used to adorn Roman buildings,[2] Pliny (*N.H.* XXXVI.48–50) successively mentions the marble from Karystos, Luna, Numidia, and *marmor Luculleum*. He says about the latter that four years after the consulship of Lepidus, who first introduced Numidian marble to Rome, i.e., in 74 B.C.: "L. Lucullus consul fuit, qui nomen, ut ex re apparet, Luculleo marmori dedit, admodum delectatus illo, primusque Romam invexit, atrum alioqui, cum cetera maculis aut coloribus commendentur. nascitur autem in Chio insula, solumque paene hoc marmor ab amatore nomen accepit." [3]

Pliny's information is summarized by Isidorus of Seville in his *Etymologiae sive Origines*.[4] There are other more laconic references concerning *marmor Luculleum*, one of which likewise derives from Pliny (*N.H.* XXXVI.6), where he informs us that M. Scaurus, aedile in 58 B.C., brought a certain number of columns made from this marble to Rome to adorn the atrium of his house on the Palatine. Each one of these columns was thirty-eight feet long – more than ten meters.

The next information comes from Diocletian's *Edict on Maximum Prices* from A.D. 301, which gives the price for *marmor Luculleum* as 150 denarii per cubic foot.[5] The green Thessalian marble cost the same, and only four of the nineteen varieties of marble mentioned in the price edict cost more, namely green *Lacedaemonius lapis*, the marble from Docimium in Phrygia, purple Egyptian porphyry, and most probably – there are lacunae in the relevant texts – the yellow Numidian marble. Less costly than *marmor Luculleum* were the

Egyptian granites: the red variety from Aswan and the gray one from Mons Claudianus, then alabaster and marbles from Karystos, Prokonnesos, Lesbos, Thasos, Skyros, and Herakleia, including four varieties not yet identified. Of course, we do not know the principles governing the prices of marble laid down in the edict, but the conclusions one can draw from comparison of the prices of individual varieties can, to some extent, be useful in discussions about *marmor Luculleum*.

Let us revert to the principal source, i.e., to the passage of Pliny quoted above.[6] The text not only gives rise to various interpretations regarding the provenance of *marmor Luculleum* but also makes it difficult to understand what its appearance was.

According to Pliny, *marmor Luculleum* was "atrum alioqui, cum cetera maculis aut coloribus commendentur." This sentence has been understood in two ways: (1) "This marble is, in general, black [dark], whereas the remaining marbles attract the eye [are recommended] because of their patches or colors,"[7] and (2) "This marble is, in general, black [dark], however, some parts of it attract the eye [are recommended] because of their patches or colors."[8]

Two versions, two diverse opinions, each of which is equally possible from the text. Pliny's description of the marble is thus not much help in identifying it, but it does at any rate exclude all the light-colored marbles and the patterned ones without any dark or black colors.

The other controversial question concerns the name of the island from which *marmor Luculleum* came. The manuscript tradition of Pliny's work gives the forms *heo*,[9] *millo*, *nilo*, *ilo*. These distinctly distorted forms have led to many attempts at identifying the correct name. Thus the editio princeps of 1469 had *Milo*,[10] which is close to some of the manuscript readings, but does not solve the factual difficulties, and in fact has not won the acceptance of later scholars.

The fifteenth-century editions were not accessible to me in the originals, but where they are quoted in later works, the indication is that already in that century attempts had been made at another reading, namely *nilo* (in Nilo insula).[11] This reading was soon changed to *Nili* (in Nili insula). This form is prevalent in sixteenth-century editions[12] and in many of the later ones and still has its adherents in the first half of the nineteenth century.[13] It is, however, true that G. Brotier (edition of 1779) in an attempt to contest the reading *nilo* and its derivation *Nili*, wrote: "Nulla insula Nilus: nec Nilus Aegyptusque tum fuere dominationis Romanae,"[14] but this does not create any basic objections to the acceptance of the version *Nili*. It is known that in the winter of 87/86 B.C. Lucullus was in Alexandria as Sulla's envoy and was received by Ptolemaeus Latyros with utmost hospitality. Therefore, we cannot discount the possibility that while in Egypt Lucullus had seen some products made of a stone that greatly appealed to him and that at some period, perhaps at a later time,[15] he had some of this marble sent to Italy. This could have been facilitated by the then king of Egypt, who at that time was already dependent on the goodwill of Rome.

But can the *marmor Luculleum* obtained by M. Scaurus also be attributed to the courtesy of the Egyptian ruler? It is a fact that Scaurus was active in the East, but nothing is known about his contact with Egypt. He may, however, not have had to search very far for this new kind of marble, for the limited number of columns he brought to Rome could have been obtained from reserves of the marble brought to Italy by Lucullus.[16]

To continue the presentation of the attempts to amend Pliny's text, we will mention, in chronological order: F. Pintianus (1544),[17] who stated that the correct form here would be *Melo* (in Melo insula). This conjecture became popular only in the second half of the nineteenth century, when several editors included it in their texts: J. Sillig (edition of 1851–1882), L. v. Ian (edition of 1854–1865), D. Detlefsen (edition of 1866–1882), C. Mayhoff (on the basis of Ian's edition, 1892–1909).[18] The *Melo* version no longer holds since the geology of the island is better known.[19] Among the rocks there is none that fits the description of *marmor Luculleum* given in the sources.[20]

Yet another attempt was made by J. Hardouin (edition of 1685), who proposed the version *chio* (in Chio insula) for the disputed place. He based this interpretation on one of the manuscripts (manuscript T) of Isidorus of Seville's *Origines*, in which, as we have seen, there is an abbreviated version of Pliny's passage. Other manuscripts of the *Origines* have *theo*, and *ceo*.[21] Hardouin's theory is repeated by G. Brotier (1779) and later by L. Bruzza,[22] and it also appears in Forcellini's *Lexicon Totius Latinitatis*.[23] The Chios interpretation, which does not seem to have had many supporters in the past, is, however, accepted by many modern scholars.[24] In addition to their reading of manuscript T of *Origines*, they base it on the fact that dark-colored marble actually does appear on Chios.[25]

The reading *chio* (together with that of *ceo*, mentioned above, see note 21), alone among all those concerning the readings of Pliny's or Isidorus's texts, is characterized by the fact that it does not call for an amendment but can be readily accepted as it stands. However, this does not mean that it is correct. The old philological maxim *lectio difficilior potior* still holds good. D. E. Eichholz, in his recent edition of Pliny's work (from which I quoted the passage given at the beginning of this paper), has "Chio" but justifiably warns in the footnote: "reading uncertain."[26] It is also characteristic that W. M. Lindsay in his edition of Isidorus's *Origines*[27] does not refer to any of the manuscripts of this work to settle this point in the text but rather accepts the version "Melo" from the editions of Pliny. The text of the *Origines*, like that of the *Naturalis Historia*, has reached us in poor condition. Lindsay is of the opinion that the protoarchetype of the *Origines* was "*vitiis passim maculatus*."[28]

The marble from Chios was identified by earlier authors,[29] though less emphatically by those nearer our times, with the so-called *Africano* marble (this name is borrowed from the traditional vernacular of the Italian masons reusing for centuries the marble from ancient ruins). At first *Africano* was not identified with *marmor Luculleum*, but that has gradually changed. One arrived at the conclusion that *marmor Luculleum* = Chian marble = *Africano*.[30] However, no marble resembling *Africano* has been discovered on Chios, while marble fitting its description (see below) was recently found at Teos by M. H. Ballance,[31] who, however, did not identify the *Africano* of Teos with *marmor Luculleum*.[32] A few years later that connection was made by Raniero Gnoli,[33] so that now the equation is *marmor Luculleum* = Teian marble = *Africano*. This equation has been accepted by scholars of recent years.[34]

The distortion of the name Teos is seen by Gnoli in the reading *heo* from the good manuscript B of Pliny. Teos is, of course, not an island (and *marmor Luculleum* is said by Pliny to have originated from an island), but, as Gnoli reminds us, Pliny did regard Teos as an island, as he distinctly says in *N.H.* V.138. The *Africano* from Teos is not an entirely dark rock like the Chian marble, although it gives the general impression of being dark. It is actually a recrystallized limestone breccia "containing lumps of white, grey or, most typically, pink marble . . . embedded in a black, dark green or greyish matrix."[35]

I shall return to this point, but I would like to complete the review of opinions regarding *marmor Luculleum* by briefly recalling two old ideas, which I know only from secondhand sources. They have, as far as I can judge, one thing in common, namely that they do not consider the difficulties caused by confused manuscript readings, but are based merely on the conviction that *marmor Luculleum* is black. On this basis, A. Nibby[36] identified *marmor Luculleum* with the stone from Alabanda,[37] while the author of the catalogue of the Ravestein collection[38] identified it with the marble from Cape Matapan.[39] Both of these interpretations represent the methods prevalent in earlier times: The stones were identified from various ancient texts without any realistic basis, which, it is true, would have been extremely difficult to establish.

It seems that the last word has yet to be said on *marmor Luculleum*. Supporters of the theory that Chios was the source of *marmor Luculleum* have not been able to prove this through comparative mineralogical analyses on the material from Chios and from Roman ruins. The gray Chian marble has been in common use locally since the earliest times,[40] but whether it ever reached Rome in antiquity has still not been established. Furthermore, not every scholar has identified a quarry from which this gray marble supposedly derived. Those who do indicate a specific quarry point to Latomion, a quarry slightly north of the island's capital.[41] However, neither the geology of this place nor the technique of exploiting the strata has been investigated. Therefore, it is not known whether the simultaneous large-scale extraction of the gray marble near the surface and the underlying red *Portasanta*[42] was feasible, nor whether it was actually practiced. If *marmor Luculleum* in fact came from this place, such simultaneous quarrying must have been going on there.

Adherents of the Chios theory of the origin of *marmor Luculleum* also need to explain the price of the marble as reported in Diocletian's *Edict on Maximum Prices*, for it seems exorbitant for a stone originating from Latomion. Except for Karystian marble, all island marbles referred to in the edict cost only a third of the price given for *marmor Luculleum*, even though island marbles were not inferior to Chian marble in quality.[43] If we seek an explanation for marble price differences in the methods of technology and transportation involved in the exploitation, there is nothing that indicates that the island quarries, including the Chian Latomion, differed markedly from each other.

As to the theory that Teos was the source of *marmor Luculleum*, the price is likewise disproportionate for that locality. In addition, the geological conditions of the area and the technique of exploitation of the strata still need to be studied. Not only *Africano* but also the gray or grayish-blue limestone or marble was quarried there for exportation. The investigations carried out by Fant in 1985–1986 on a slender budget did not throw any light on these questions.[44] The chronology of the initial phases of quarrying at Teos – which is of the greatest importance for this problem – also remains obscure.

Africano from Teos had its main use between the times of Augustus and the Antonines, and the quarry itself fell into disuse about A.D. 170.[45] The earliest presence of *Africano* in Italy can be dated to between 36 and 33 B.C., i.e., about forty years after Lucullus's consulship.[46]

These dates seem to be important. It should be remembered that the exploitation of *marmor Luculleum* must have started at some date prior to the time the Roman dignitary took charge of it. Furthermore, this period could not have been very short, since Lucullus could have become interested in this marble only after seeing it in the form of finished products, for no stone is attractive in its raw, unworked state but rather attains its beauty only after it has been smoothed and polished. Lucullus would not have spared the raw stone a second glance.[47] Thus, already at the time of Lucullus's consulship (74 B.C.) or, at the latest, in 58 B.C. when Scaurus erected the more than ten-meter-high columns in his atrium, the quality of the marble and its suitability for such use was well recognized, and exploitation of the quarry must have been well established.

Geological conditions vary throughout any individual quarry, but on the whole, during the first years of exploiting a quarry, it is impossible to obtain large and adequately strong blocks, since the upper strata of the rock, nearer the surface of the soil, are brittle and cracked as a result of weathering. Columns the size of those Scaurus erected in his atrium in 58 B.C. can thus only have been obtained from a quarry that had been in operation for some time.

What was the situation at Teos? Further investigations are required to answer this question, but it should be pointed out that not only has the date of the earliest exploitation of this quarry not been established but there also are some discrepancies between the confirmed date of termination of quarrying (about A.D. 170) and the date of the price edict (A.D. 301), which, as we have seen, mentions *marmor Luculleum*. So far, attempts to resolve these difficulties have contributed nothing of significance.[48]

In the event, equating *marmor Luculleum* with marble from Teos cannot be accepted unequivocally. Consequently, other theories concerning the origin of the marble cannot be rejected if they contain a reasonable dosis of probability. Thus we cannot discount the possibility of a Chian provenance, nor the earlier theories pointing to the Nile. In Egypt there is no lack of attractive dark gray and black stones suitable for polishing and hence falling within the range of the Roman notion of marble: certain varieties of basalt and granite, stones that are best known to us from Pharaonic times. They were obtained, among other places, near Aswan on the right bank of the Nile and on the islands in the vicinity.[49] Not much is known about their exploitation during Hellenistic and Roman times.[50] On the other hand, the provenance of the gray and black "marbles" from Roman ruins has still not been satisfactorily investigated. For now, as knowledge about the marbles used in antiquity is expanding, I would like to propose that scholars take into account the problems discussed in this paper.

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Notes

Blümner:
H. Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern*, vol. 3 (Leipzig, 1884).

Fant:
J. C. Fant, "Poikiloi Lithoi: The Anomalous Economics of the Roman Imperial Marble Quarry at Teos" (forthcoming in the *Proceedings of the Xth British Museum Classical Colloquium*).

Gnoli:
R. Gnoli, *Marmora Romana* (Rome, 1971).

The text was translated from Polish by Lorraine Tokarczyk. I am deeply grateful to Benedicte Gilman for her help in the preparation of the text for print.

1 Beginning with Gnoli.

2 In fact, building marble had appeared in Rome much earlier. The first date mentioned by scholars for this is 146 B.C. when, after the conquest of Macedonia, Q. Metellus brought back to Rome a considerable amount of (undoubtedly looted) marble for his temple and portico on the Campus Martius. The information we have about somewhat later years refers to Pentelic and Hymettian marbles, which were sporadically brought back to Rome. Both belong to the white varieties and derived from the old quarries that had been exploited for centuries. However, at the transition from the second to the first century B.C., the flow of this material to Rome was checked, a state of affairs that lasted until the times mentioned by Pliny, *N.H.* XXXVI.48–50. This lull in the use of marble in Rome is attributed by scholars to the threat to maritime transports posed by pirates. See recently F. Rakob, "Hellenismus in Mittelitalien: Bautypen und Bautechnik," in *Hellenismus in Mittelitalien, Kolloquium in Göttingen, 5–9 Juni, 1974*, vol. 2 (Göttingen, 1976), p. 367. However, in the times Pliny writes about, a new quality in the marble import appears: colored, variegated marbles were brought to Rome (even the marble from Luna, referred to by Pliny, did not have to be white: it could be the gray, patterned variety, so-called *bardiglio*). Colored marbles did not begin to come into use in the Greek world until the Hellenistic period. Before then only the gray and black marmarized limestone had been used, although usually more out of necessity than for decorative purposes. The new fashion in colored marble could have come from Egypt, for there varieties of colored stones had been exploited since prehistoric times.

3 Pliny, *N.H.* XXXVI.49. Text given after Pliny, *Natural History*. Vol. 10 of Loeb Classical Library, D. E. Eichholz, ed. (London and Cambridge, Mass., 1962).

4 Isid., *Orig.* XVI.5, 17.

5 *Ed. Dioclet.*, I.31, 4, M. Giacchero, ed. (Genoa, 1974).

6 Apart from this, there is facultative evidence from Strabo IX.437. Some scholars have attempted to correct there the distorted readings Deukalliou, Deukalias, and Deukollias by changing them to Leukolleias. This would then have meant *marmor Luculleum*. Strabo is writing here about colored, variegated marbles. See Gnoli, p. 149 and n. 1 (after Tzschucke); Fant, p. 2. My thanks are due to Dr. J. C. Fant for his kindness in making his paper available to me before it went to press. I am quoting pages according to the copy of the manuscript he sent me.

7 The text is so understood by F. Corsi, *Delle pietre antiche*, 3rd ed. (Rome, 1845), p. 167; Blümner, p. 45; G. Lafaye, "Marmor," in C. Daremberg and E. Saglio, *Dictionnaire des antiquités grecques et romaines*, vol. 3 (Paris, 1902), p. 1602; Ch. Dubois, *Etude sur l'administration et l'exploitation des carrières (marbre, prophyre, granit, etc.) dans le monde romain* (Paris, 1908), p. 126; M. E. Blake, *Ancient Roman Construction in Italy from the Prehistoric Period to Augustus* (Washington, D.C., 1947), p. 58; M. Guarducci, "Un nuovo frammento dell' editto di Diocleziano," *Bull. del Museo dell' Impero Romano* 12 (1940), p. 44; J. B. Ward-Perkins, "Marmo," *EAA*, vol. 4 (1961), p. 869, cf. p. 867; Eichholz (note 3), p. 39. The word "cetera" is understood by some as referring to the marbles previously mentioned in Pliny's passage.

8 This is how it is understood by L. Bruzza, *Iscrizioni dei marmi grezzi*. Vol. 42 of *Ann. Inst. di corrisp. archeologica* (1870), p. 143; Gnoli, p. 149; Fant, pp. 2f.

9 Thus in the Bambergensis manuscript (B), known only from 1831, which is generally considered to be one of the best.

10 I am quoting from the London edition of 1826, based on Brotier's edition (1779), ad locum.

11 H. Barbarus, *Castigationes Plinianae* (Rome, 1492, 1493, I. B. Palmari, editions of 1499 and 1518).

12 I am quoting as examples: A. Benedictus (editions of 1507 and 1516); Erasmus Roterodamus (edition of 1525); S. Gelenius (editions of 1535 and 1616); J. Dalecampius (editions of 1587 and 1599). The same applies to the first author who wrote on antique marbles: B. Caryophilus, *De antiquis marmoribus* (Vindobonae, 1738), p. 109.

13 Among those known to me are the anonymous edition from Tauchnitz publications (1830); Delafosse (edition of 1831); and Corsi (note 7), p. 107, who was of the opinion that this referred to the largest island in the Nile, known in antiquity as Meroe, in Ethiopia. This is mentioned tentatively by Caryophilus (note 12), but it is purely theoretical and based on the assumption that Pliny should have indicated which of the islands in the Nile he had had in mind. It should be added that Blümner, p. 45, n. 3, mentions, after Ch. de Clarac, *Musée de sculpture antique et moderne*, vol. 1 (Paris, 1826), p. 168, that the supporters of the Nile version considered *marmor Luculleum* to be African or Numidian marble.

14 I am quoting from the London edition of 1826, based on Brotier's edition, ad locum.

15 It is true that Lucullus was received at the royal palace, but during his stay there he firmly refused to accept the generous gifts offered him by the Egyptian ruler.

16 Fant, p. 4, is of the opinion that Lucullus could have brought this marble to Italy, not because he fancied it but for commercial purposes. To pursue this line of thought, it may be assumed that the marble received its name only after Scaurus obtained it from Lucullus, and thus the name had nothing to do with the location of the quarry, as was the usual practice in naming marble.

17 F. Pintianus, *In C. Plinii naturalis historiae libros omnes observationes* (Salmanticae, 1544).

18 The Melo theory is still encountered in our times. See S. Ferri, *Plinio il Vecchio: Storia delle arti antiche. Testo, traduzione e note* (Rome, 1946).

19 On this, see A. Philippson, *Die griechischen Landschaften*, vol. 4 (Frankfurt am Main, 1959), pp. 186–196. As regards the antique quarries discovered on the island of Melos, see A. Dworakowska, "Carrières antiques dans les Cyclades: Matériaux pour l'inventaire" (in Polish, with French summary), *Archeologia* (Warsaw) 22 (1971), p. 90, no. 35; pp. 93f., no. 47; p. 94, nos. 48, 50; see also p. 99, no. VII; p. 100.

20 Blümner, p. 46, also drew attention to this. Cf. Dubois (note 7), p. 125.

21 Blümner, p. 45, n. 3, considered that these readings could also have referred to the islands of Keos or Kos. It would not seem as if scholars had been interested in these islands as the provenance of the *marmor Luculleum*. In any case, this version is not acceptable for the same reason that Melos is not.

22 Bruzza (note 8), pp. 143f.

23 Ae. Forcellini, *Lexicon Totius Latinitatis* (Furlanetto's edition, 1827), F. Corradini and J. Perin, eds. (1940), s.v. "Chius."

24 Guarducci (note 7), p. 44; Ward-Perkins (note 7), pp. 867, 869; Eichholz (note 3), p. 39 (with reservations, see above); M. H. Ballance, in K. Erim and J. Reynolds, "The Copy of Diokletian's Edict on Maximum Prices, from Aphrodisias in Caria," *JRS* 60 (1970), p. 134.

25 It is actually a black and grayish-blue marmarized limestone. This is discussed in A. Dworakowska, "Carrières antiques des îles d'Asie Mineure depuis Lesbos jusqu'à

Icarie: Matériaux pour l'inventaire" (in Polish, with French summary), *Archeologia* (Warsaw) 28 (1977), pp. 98f., nos. 2–4; pp. 107, 113.

26 Eichholz (note 3), p. 39, n. b.

27 W. M. Lindsay, ed., *Isidori Hispalensis Etymologiae sive Origines* (Oxford, 1911). F. Arevallus in his edition of 1797–1803, which is known to me from a reprint in J. P. Migne, *Patrologiae cursus completus*, Series latina, vol. 82 (Paris, 1878), prints "Chio." The old edition of B. Vulcanius (1577) prints "Choo," and in a marginal note is written: "al. Chio." The version "Choo" is also mentioned by Blümner, p. 45, n. 3. Cf. note 21.

28 Lindsay (note 27), p. xii.

29 I shall mention as examples a few names among many: A. Nibby, *Del Foro romano, della via sacra, dell' anfiteatro flavio e de luoghi adjacenti* (Rome, 1819), pp. 34f; Corsi (note 7), p. 99 (after Furlanetto); X. Barbier de Montault, *Tableau raisonné des pierres et marbres antiques employés à la construction et à la decoration des monuments de Rome*. Bulletin Monumental, 4. series, 5 (25) (1869), p. 850; A. Moretti, "Marmo," *EAA*, vol. 4 (1961), p. 863. Cf. also Blümner, p. 56.

30 Forcellini (note 23), s.v. "Chius"; Bruzza (note 8), pp. 143f.

31 M. H. Ballance, "The Origin of 'Africano,'" *BSR* 34, n.s. 21 (1966), pp. 79–81.

32 Ballance (note 24), p. 134.

33 Gnoli, pp. 148ff.

34 P. Pensabene, "Considerazioni sul transporto di manufatti marmorei in età imperiale a Roma e in altri centri occidentali," *Dialoghi di archeologia* 6 (1972), p. 360; Fant, passim.

35 Ballance (note 31), p. 79; Fant, p. 1. Samples of stone from Roman ruins are described by Gnoli, p. 147; colored reproductions of samples: ibid., figs. 133, 134, 197.

36 I am giving his opinion after Bruzza (note 8), p. 143.

37 Judging from what Pliny writes (*N.H.* XXXVI.62), the stone from Alabanda was neither marble nor a building stone.

38 *Catalogue of the Ravestein Collection, Musée Cinquantenaire, Brussels.* I am citing from M. Winearls Porter, *What Rome Was Built With* (London and Oxford, 1907), pp. 70, 93. Blake (note 7), p. 58, also alludes to this conception.

39 Ancient Cape Tainaron. Pliny, *N.H.* XXXVI.135 and 158 mentions the black stone from Tainaron, but the history of its utilization has not been investigated and the quarries were not recognized until recently. See F. A. Cooper, "The Quarries of Mount Taygetos in the Peloponnesos, Greece," in N. Herz and M. Waelkens, eds., *Classical Marble: Geochemistry, Technology, Trade* (Dordrecht, 1988), p. 68.

40 Cf. note 25.

41 Ward-Perkins (note 7), p. 869; Ballance (note 24), p. 134.

42 *Portasanta* seems to have been known in antiquity under the trade name of *marmor Chium*.

43 Cf. Gnoli, p. 151.

44 Fant, p. 5. A final report on this research has been promised (ibid., p. 12 and nn. 5 and 7; p. 20, n. 44). Investigations are hampered by the fact that the pit from which the *Africano* marble was most probably extracted is now inundated by a small lake, which has not yet been fully penetrated.

45 Ballance (note 31), p. 79; Fant, p. 6, n. 20, p. 44. The dating was facilitated by the quarry marks cut into dressed blocks.

46 Blake (note 7), p. 56. In the year 36 B.C. Agrippa used *Africano* in the vestibule of his tunnel at Lake Avernus, and Blake assumes that it was Agrippa who introduced this marble to Rome. The date of the erection of the *Africano* columns in the Basilica Aemilia in the Forum Romanum, which was rebuilt several times in the first century B.C., is unknown, but Blake (ibid., p. 56 and n. 11) is inclined to attribute this to the reconstruction in 34 B.C., while F. Coarelli, *Roma: Guide archeologiche Laterza* (Rome,

1982), p. 45, attributes it to the reconstruction of 78 B.C.

47 Fant, p. 4, writes: "I suspect that Lucullus had acquired control of the quarry at Teos during his years in the East." This is all very well, but Lucullus would have had to realize in advance that the quarry was worth further trouble, and this very fact should have been established.

48 Gnoli, p. 148, n. 3, presents this problem from the point of view of one who is entirely convinced of the identity of these two marbles, which excludes the possibility of any discussions on the question. Fant, on the other hand (p. 20, n. 44), supposes that there could have been some smaller quarries operating at a later date, which were located in the vicinity of the main one known today (which is now inundated). However, investigations are still going on, and at the moment no new information, even of a provisory nature, has been made available.

49 A. Lucas, *Ancient Egyptian Materials and Industries*, 4th ed., rev. and enlarged by J. R. Harris (London, 1962), p. 58. See also, e.g., H. Kees, "Ägypten," in I. Müller and W. Otto, *Handbuch der Altertumswissenschaft*, Abt. 3, Teil 1, vol. 3 (Munich, 1933), p. 138; Dubois (note 7), p. 74 (after De Rozière, *Description de l' Egypte*, vol. 1 [Paris, 1809], Appendix 1, §2). J. A. Harrell, "An Inventory of Ancient Egyptian Quarries," *Newsletter, American Research Center in Egypt* 146 (1989), pp. 1–7 (*non vidi*).

50 See brief mentions of these varieties in Gnoli, p. 121; Pensabene (note 34), p. 359.

Weathering Layers and the Authentication of Marble Objects

Richard Newman

The authentication of stone objects can often prove very problematic. William J. Young's 1968 article on the Boston Museum of Fine Arts' Greek three-sided relief (circa 470–450 B.C.) is an often-cited example of an authentication study of an ancient marble object.[1] His study combined a number of pieces of evidence, principally involving alteration and weathering of the surface. He studied the surface under a microscope to look for evidence of erosion of the stone along grain boundaries and observe root marks and other encrustations. Scrapings of encrustations were analyzed by X-ray diffraction to identify crystalline phases. Emission spectrographic analyses were carried out on scrapings of encrustations to search for anomalies that might suggest an "applied" patina. Young also examined the surface in ultraviolet light: Freshly broken or cut marble fluoresces differently than older worked surfaces, and thus this technique can be valuable in answering questions regarding possible recarving or the relative age of some damages. It can also be valuable in comparing the alteration or weathering that different objects have undergone.

Young studied the "patina" of the marble with the aid of a thin section of the rock and its surface. In his many years as director of the Research Laboratory at the Museum of Fine Arts, Young relied extensively on the examination of this type of sample in the authentication of ancient marble objects. He built up a collection of samples from objects of undoubted authenticity, as well as from recent marble sculptures and fakes.[2] Regarding this type of evidence, Young wrote in his article on the three-sided relief, "While no claim is made for this technique as a precise method of dating objects, it has proven invaluable in helping to establish the authenticity of many works of art."[3] He noted that he had not observed such layers on fakes or recent marble objects but almost invariably found them on authentic, old objects.

Although more than twenty years have passed since the publication of Young's article on the three-sided relief, much the same types of examinations would be carried out in similar authentication studies today. Examinations with a microscope under low magnification and in ultraviolet light are still among the most valuable

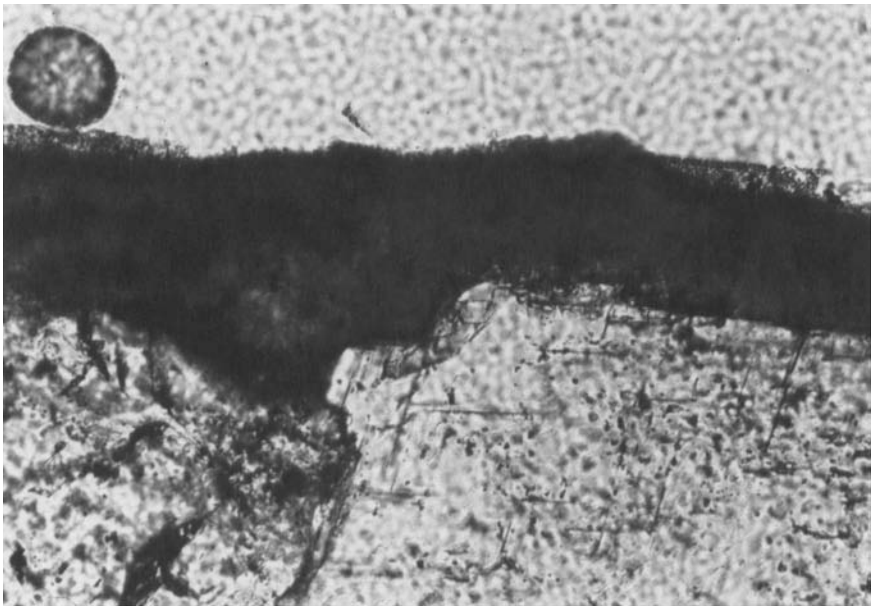


FIG. 1a

Roman sarcophagus fragment, early fourth century A.D. Photomicrograph by transmitted plane-polarized light of thin section. Magnification 200×, width of field 0.53 mm. Boston, Museum of Fine Arts TL 19.183b. Photos: author.

techniques available. Weathering layers, in spite of the fact that they seem to offer little possibility of providing any specific age for a worked marble surface, also continue to be a valuable tool in authentication studies. The major advances in the scientific examination of classical marble objects since that time have occurred in the realm of determination of quarry origins, as discussed elsewhere in this volume, although this information often has little direct bearing on the authentication of problematic objects.

In this article, the origins of weathering layers on marble are reviewed. Different weathering phenomena can be expected to take place on marbles that consist mainly of calcite than on those consisting mainly of dolomite, and examples of both types of marble are included in the discussion. "Patina," "alteration layer," and "weathering layer" are more or less interchangeable terms as Young used them; for convenience, in this article "weathering layer" will be used to describe all types of layers that form on marble surfaces during burial or aboveground exposure.

SAMPLES AND EXAMINATION METHODS

The weathering layers that develop on marble surfaces tend, even after extended periods, to be relatively thin, usually only a fraction of a mm. They are best studied in cross-sections that include both the weathered surface and the interior (unaltered) stone. The cross-sections are prepared from small chips of rock, which need be no more than one square cm in surface area and may be smaller. They can be taken with fine chisels, hollow-core drills, or other tools. Although opaque cross-sections can be examined, for study by optical microscopy the most useful sample is a thin section. These are transparent slices of rock

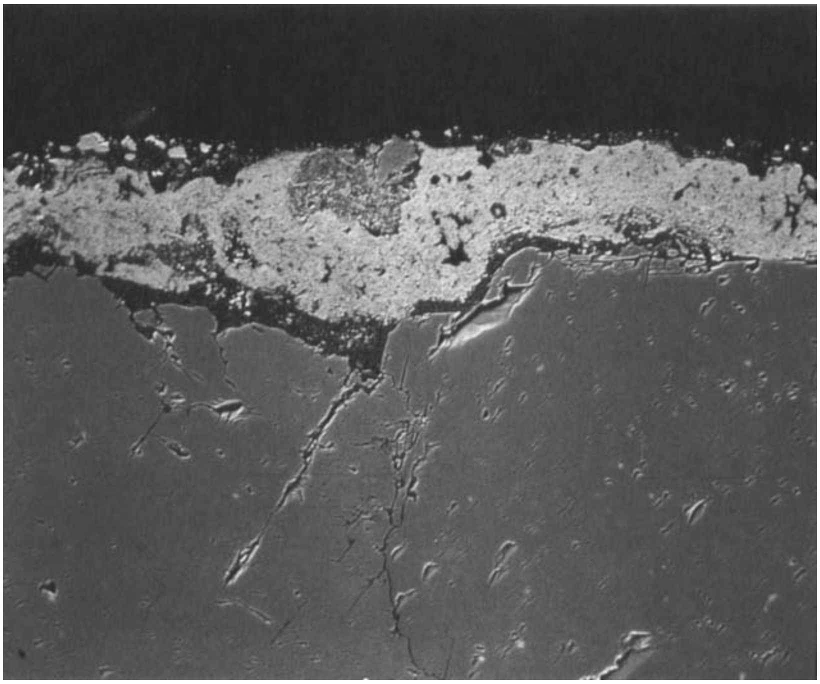


FIG. 1b

Back-scattered electron micrograph of thin section, figure 1a. Magnification 200×, width of field 0.53 mm.

mounted on glass slides and sanded to a thickness of about .030 mm, a type of sample routinely used by geologists to study rocks. William Young generally extracted the sample chips with strong solvent for several hours to insure that any wax or organic coating that might have been applied to the surface was removed. In the past at the Museum of Fine Arts, the thin sections were prepared in standard fashion with cover slips and examined with a polarizing (petrographic) microscope. The fine-grained weathering layers, often slightly stained by iron compounds, are generally readily visible, although it is rarely possible to identify the minerals or compounds present in the layers on various sculptures because of their very fine-grained nature.

Thin sections can also be prepared without cover slips, which permits them to be examined not only in optical microscopes but also in electron beam instruments, such as scanning electron microscopes or electron beam microprobes. With the latter instruments, the compositions of these thin surface layers can be analyzed with attached X-ray fluorescence spectrometers, and structural details can usually be more easily visualized.[4] Figure 1 compares the appearance of a thin section viewed by transmitted light in a petrographic microscope with the same section viewed in an electron beam microprobe. Virtually all illustrations included in this article are of newly prepared polished thin sections photographed in a microprobe.

There are different ways of "imaging" samples in electron beam instruments; all of the images included in this article were created by back-scattered electrons, which are generated as a function of atomic number. The images are in some respects similar to those that would be seen if the samples were observed by reflected light in an ordinary microscope in that they show topographical details such as fissures in the rock and the different textures of the polished minerals and weathering layers. The shades of gray, however, are for the most part a function of atomic number: areas containing heavier elements show lighter shades of gray than areas containing lighter elements.

Some of the samples remain from examinations carried out in the past, while others were taken for this article. The number of objects sampled was very limited, and thus the illustrations should be regarded only as an indication of some of the forms the weathering layers may take on different types of marble. Since each sample represents only a small part of the surface of a marble sculpture, it is not necessarily representative of the weathering over the entire surface. There are additional analytical techniques that can provide further valuable information on weathering layers, as discussed by Margolis elsewhere in this volume; this article is restricted to what can be learned by optical microscopy and microprobe analysis.

WEATHERING OF MARBLE

Most rocks and the minerals of which they are composed were formed under temperature and pressure conditions considerably different than those present at or near the earth's surface, and they are not highly stable under surface conditions. Weathering of rocks involves both physical and chemical factors. Among these are the action of organisms such as lichens, heating and cooling cycles, and, most importantly, the action of water.[5] Minerals are generally quite insoluble, and thus actual dissolution is a comparatively slow process. Rates for a specific mineral will vary considerably, depending on acidity or alkalinity of the water and the chemical species in solution in the water. Marble and limestone – rocks that often consist predominantly of calcium carbonate (or more rarely calcium magnesium carbonate) – are unusually susceptible to solution. In neutral water, calcium carbonate is only slightly soluble: about 0.01 g of a piece of calcitic marble placed in a liter of water would go into solution.[6] Natural waters, whether groundwaters or precipitation, are naturally buffered by dissolved carbon dioxide. Calcium carbonate is more soluble in neutral buffered water (0.3 g/l) than pure neutral water free of carbon dioxide, and the solubility increases as the acidity of the water increases.[7] For example, at pH 6 (slightly acidic conditions), the solubility is 1.7 g/l.

The acidity of natural waters varies considerably; while some are alkaline, many are acidic. Some of the complex organic components of soils (humic acids, for example) are also acidic. When somewhat acidic water moves over a marble surface, constantly carrying away dissolved ions, the exposed rock surface can be

FIG. 2

Left side of Greek three-sided relief, probably about 470–450 B.C. Detail of eroded marble surface exposing individual grains of the marble. Magnification 10×. Boston, Museum of Fine Arts, Henry L. Pierce Fund (from Young and Ashmole, p. 132).

eroded quite rapidly, at least on the scale of geological time and normal rock weathering processes. Solution extends first along grain boundaries and can lead to losses of individual grains or clumps of grains. A detail of the surface of a highly eroded marble is shown in figure 2, and a thin section of an eroded surface in figure 3. Individual crystal faces of the carbonate grains are less readily attacked than the grain boundaries, as can be seen on both the macroscopic and the microscopic scale.

Graphic examples of the solubility of calcium carbonate rocks in acidic conditions are all too readily visible in industrial or urban areas, where marble gravestones or monuments are severely eroded as a result of the effects of acidic deposition or precipitation that arise from air pollution. Recession rates as high as about seven mm per one hundred years have been estimated for marble surfaces in some polluted environments.[8] Acid precipitation in polluted areas is regularly ten to a hundred (or more) times as acidic as mildly acidic (pH 6) natural water.

The important classical marbles consist primarily of one of two carbonate minerals, calcite ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$), and discussion in this article will be restricted to their degradation. Marbles may contain smaller amounts of other minerals, which if exposed on surfaces may also degrade. Degradation of

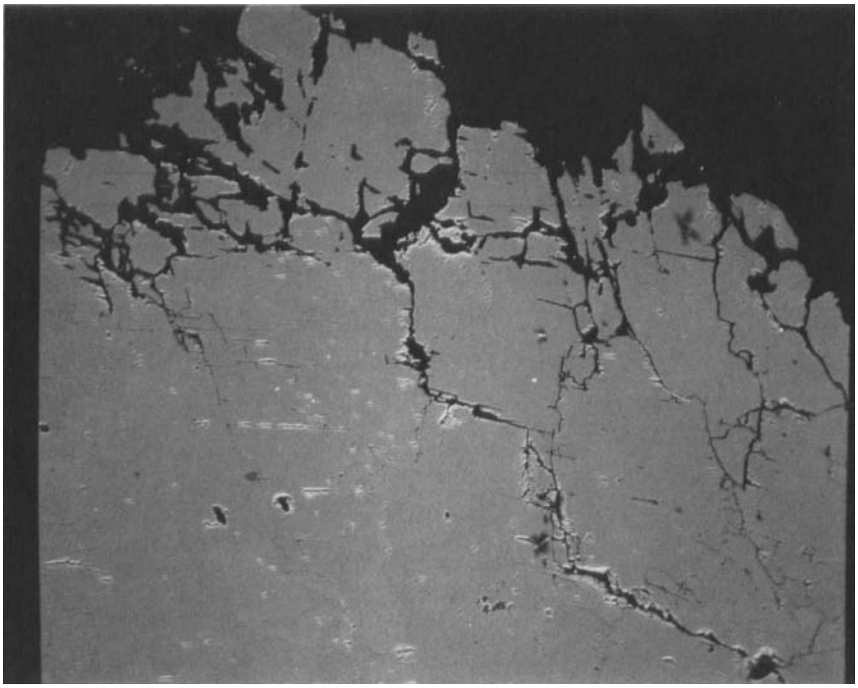


FIG. 3

Thin section of pedestal, probably from the late nineteenth or early twentieth century, showing highly eroded calcitic marble that has been exposed to atmospheric weathering in the Boston area for about ninety years. There is no weathering layer but the surface has been extensively eroded, dissociating grains of the rock. Back-scattered electron micrograph. Magnification 135 ×, width of field 0.78 mm. Boston, Isabella Stewart Gardner Museum. Photo: author.

some of these can also be quite important in authentication of some objects, one published example of which is an article on Cycladic marbles by Thimme and Riederer.[9]

Research on marble quarries in the Mediterranean area has shown that the vast majority of sculptural and architectural stones are predominantly or entirely calcitic. A few contain minor amounts of dolomite. Only three seem to contain substantial amounts of dolomite: quarries in the northeastern part of the island of Thasos (Cape Vathy area)[10] and two Anatolian sources: the island of Marmara and Denizli.[11]

The solubility of dolomite in neutral water is about the same as that of calcite,[12] but it is noticeably less susceptible to acidic water. Geologists in the field commonly distinguish calcite from dolomite by placing a few drops of dilute acid on the rock surface: calcite readily decomposes, but dolomite is barely affected. Exposed surfaces of rocks that contain both minerals are often more eroded in their calcitic than their dolomitic areas. This is visible on a microscopic scale in figure 4, where the dolomitic grains have been noticeably less weathered than the calcite grains. Because of potential differences in weathering, calcitic and dolomitic marbles will be discussed separately.

It is safe to assume that the weathering layers on most of the classical sculptures in museum collections developed in burial environments, probably including all of those discussed here. Some classical objects – those from still-standing architectural monuments – will obviously only have been exposed to atmospheric weathering, which does not produce the same kinds of layers as burial environments. The discussion in this article will be restricted to

FIG. 4

Thin section of base of a Roman cinerary chest of calcite-dolomite marble showing essentially no weathering layer but a partially disintegrated surface caused by erosion. Calcite grains (C) appear more disintegrated than dolomite grains (D). Back-scattered electron micrograph. Magnification 200×, width of field 0.53 mm. Boston, Isabella Stewart Gardner Museum. Photo: author.

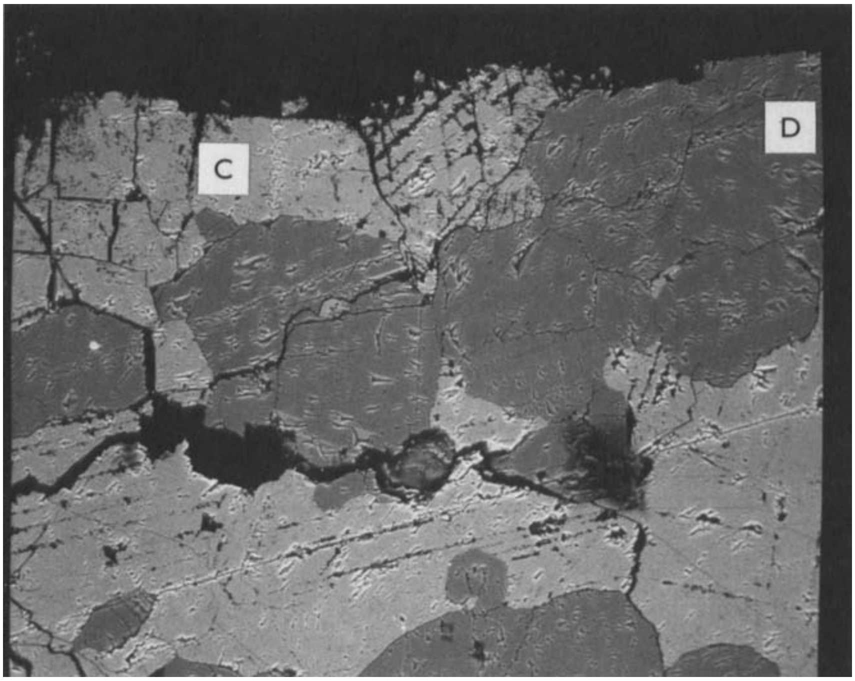
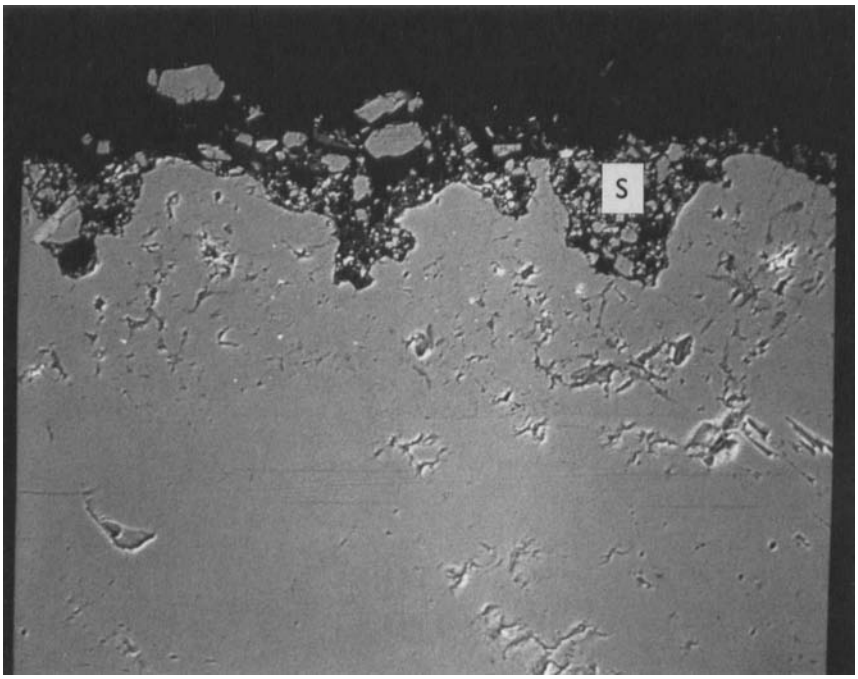


FIG. 5

Thin section of base of an Archaic Greek grave stele in the form of a seated sphinx, about 535–530 B.C., showing weathering layer (S) on calcitic marble consisting of small grains of calcite in a finer matrix that is rich in calcium and contains a little silicon and aluminum. Back-scattered electron micrograph. Magnification 400×, width of field 0.26 mm. Boston, Museum of Fine Arts 40.576. Photo: author.



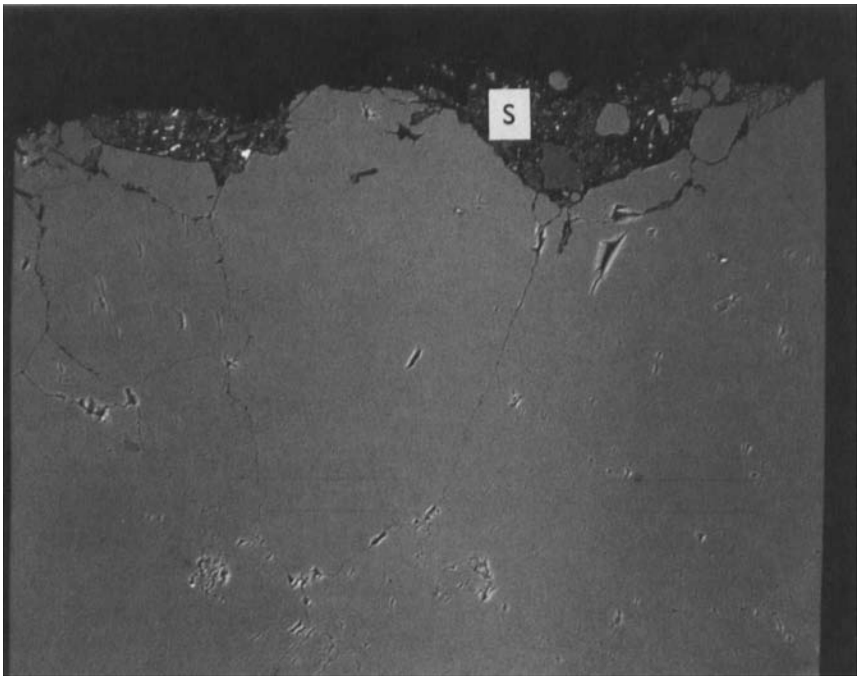


FIG. 6a

Thin section of Greek Aphrodite, fifth century B.C., showing a locally thick soily weathering layer (S) on the calcitic marble. Back-scattered electron micrograph. Magnification 200×, width of field 0.53 mm. Boston, Museum of Fine Arts Research Laboratory Reference Collection, C.5. Photos: author.

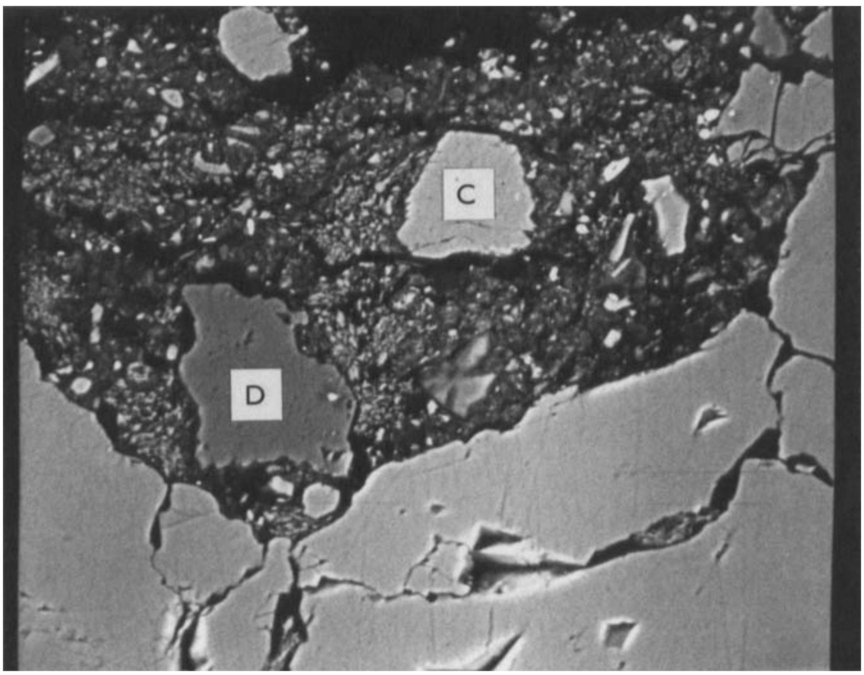


FIG. 6b

Detail of figure 6a showing weathering layer with large grains of calcite (such as C) and rare dolomite (such as D) in a fine, clay-rich matrix that contains scattered calcium carbonate and quartz grains, iron-titanium oxide, and apatite. Magnification 800×, width of field 0.13 mm.

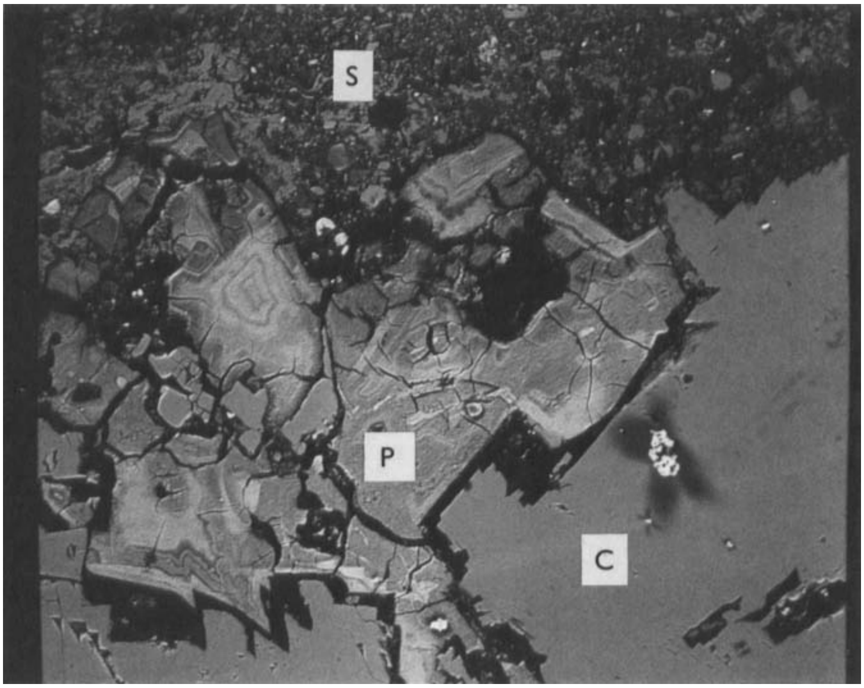


FIG. 7

Thin section of Roman sarcophagus relief, third century A.D., showing thick calcium phosphate layer on calcitic marble. Patches of precipitated calcium phosphate (P) appear on the surface and in fissures of this calcitic marble (C). Overlying this is a soily weathering layer (S) containing clay, calcite, and iron oxide(s). Back-scattered electron micrograph. Magnification 200×, width of field 0.53 mm. Boston, Museum of Fine Arts TL 19.183a. Photo: author.

weathering layers that can be assumed to have resulted from burial.

Calcitic Marbles. Figures 5–8 are examples of weathering layers on calcitic marbles. Maximum thicknesses of the layers vary from approximately 0.05–0.10 mm. Considerable variations within single samples are usual, the thickest areas tending to occur in recesses or lower areas of the rock surface, while protruding grains may contain no layer. Although many variations were encountered, in the most typical case (see figs. 5, 6) microprobe analysis of the fine-grained areas of the weathering layers showed calcium, silicon, aluminum, and some potassium and iron. The calcium is probably in the form of calcium carbonate, which may have formed by reprecipitation of calcium liberated by dissolution of the marble, combining with carbonate ions from the rock itself or percolating groundwater. Aluminum, silicon, and potassium are probably mostly in the form of clay minerals from the soil in which the object was buried; iron in the form of fine-grained oxides from the soil gives the layer a slight or substantial tint. Small dissociated grains of calcium carbonate from the rock are often trapped in this fine-grained layer. Grains of other minerals from the burial soil may also be distinguishable (see fig. 6b).

One sample (fig. 7) contained a locally thick calcium phosphate alteration layer, indicating an environment rich in phosphate ions (perhaps from bones?). The phosphate showed a banded structure, indicating deposition over an extended period of time in several cycles, and was overlaid by a more typical soily layer. Another sample (figs. 8a–b) contained a fine-grained calcium carbonate layer overlaid by a thinner powdery layer of calcium sulfate; this weathering layer presumably formed in a lime-rich environment.

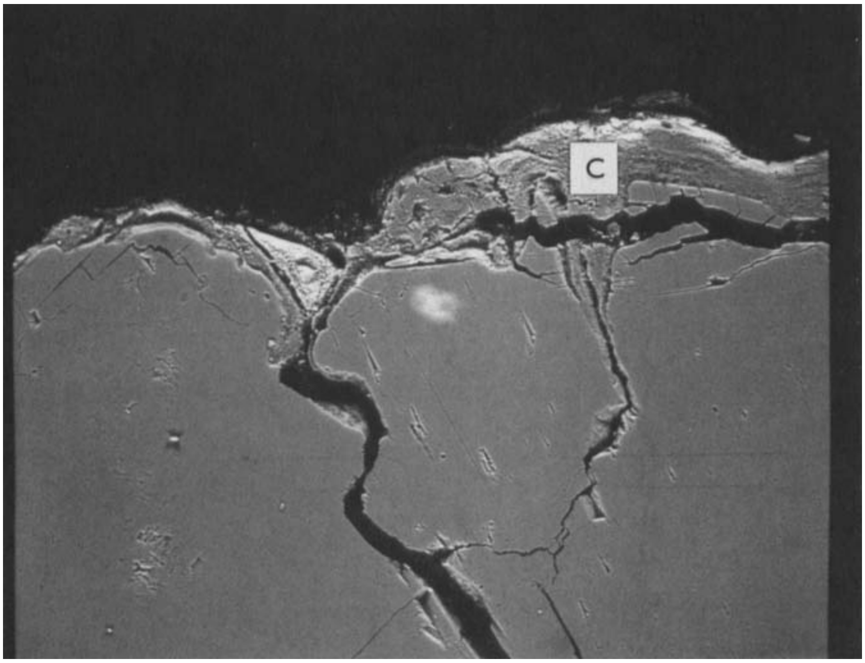


FIG. 8a

Thin section of Greek head of a goddess, fourth century B.C., showing weathering layer on calcitic marble consisting mainly of fine-grained calcium carbonate (C). The layer extends into fissures in places. Some calcium sulfate is present within this layer and also as a thin crumbly layer on top of the calcitic layer. Back-scattered electron micrograph. Magnification 200×, width of field 0.53 mm. Boston, Museum of Fine Arts Research Laboratory Reference Collection C.4. Photos: author.

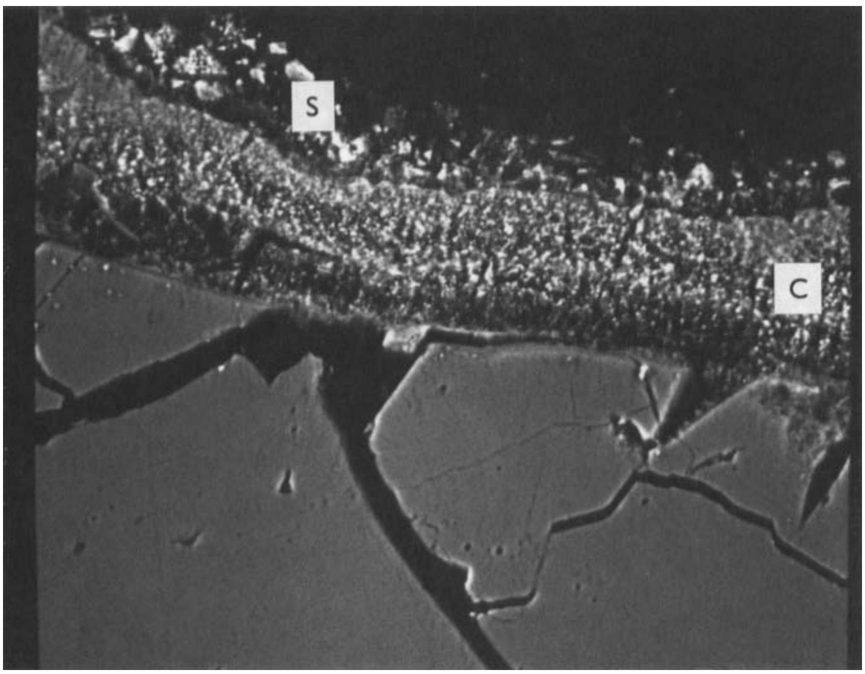


FIG. 8b

Detail of figure 8a showing calcitic layer (C) and crumbly calcium sulfate (S). Magnification 800×, width of field 0.13 mm.

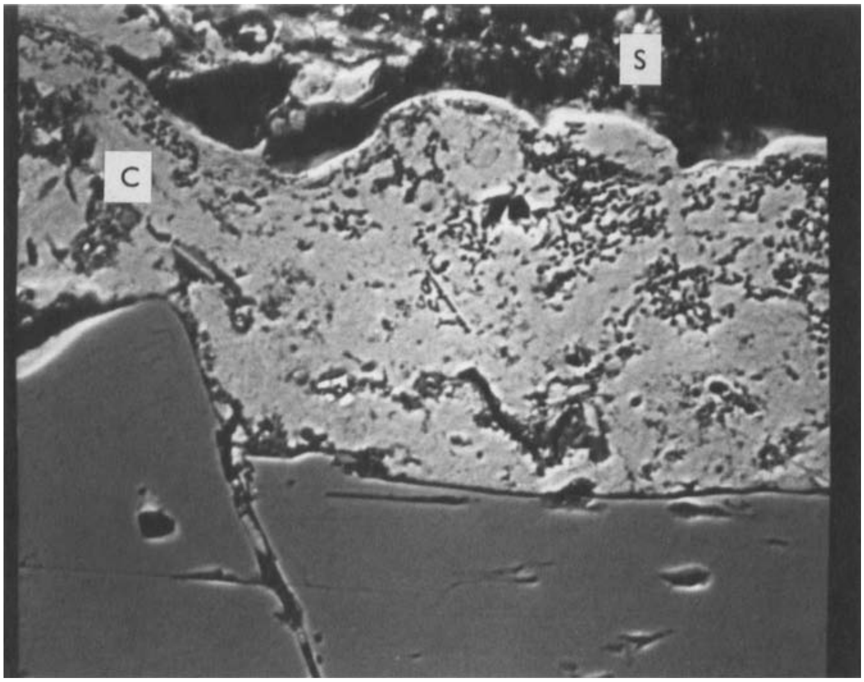


FIG. 9

Thin section of Roman sarcophagus relief, early fourth century A.D., showing compact calcitic weathering layer (C) on dolomitic marble. A soily layer (S) appears over the calcitic layer in places, and there are patches rich in silicon and aluminum within the calcitic layer. Back-scattered electron micrograph. Magnification 1034×, width of field 0.10 mm. Boston, Museum of Fine Arts TL 19.183b. Photo: author.

Small amounts of sulfur were only occasionally detected in the weathering layers, never enough to account for more than a small proportion of the calcium compounds in the layers themselves. This fact distinguishes these layers from those that form on marble objects in modern polluted environments, in which sulfates are quite commonly produced and deposited in grain boundaries or on exposed surfaces, sulfur dioxide or sulfuric acid being the major acidic components of polluted air. It is possible that groundwater in some burial environments may be rich in sulfate ions, leading to deposition of calcium sulfate(s) on eroding surfaces, but this does not appear to be very common judging from the few objects examined here.

Although there are compositional differences, common to all the alteration layers is that they are very distinct from the underlying rock substrate. The interfaces sometimes are smooth crystal faces of calcite grains and at other times are eroded grains, implying a more aggressive weathering environment. Grain boundaries near the surfaces are often at least somewhat open and are sometimes partially filled by weathering products.

Dolomitic Marbles. Calcium carbonate dissolves to yield calcium and carbonate ions, which is referred to as a congruent solution process. The geological record indicates that dolomite apparently dissolves incongruently (at least in certain situations) to yield solid calcium carbonate and magnesium ions. This process, called dedolomitization, leaves a calcium carbonate layer on a dolomitic substrate.[13] Although not well understood, dedolomitization has been observed by geologists to occur on many dolomitic rocks.

Examples of weathering layers on dolomitic

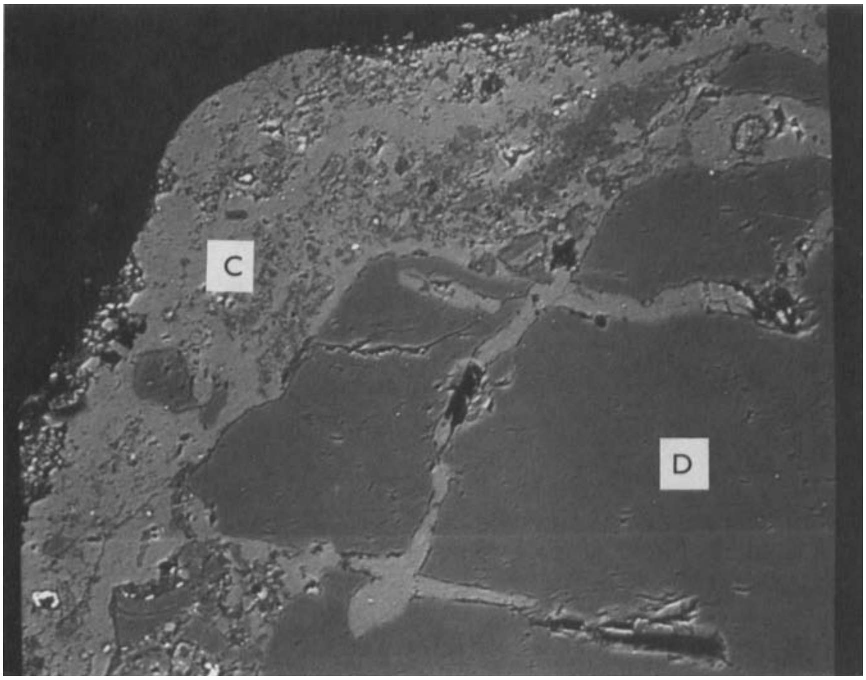


FIG. 10

Thin section of fragment of Graeco-Roman Meleager sarcophagus(?), A.D. 180–210, showing calcitic weathering layer (C) on dolomitic marble. The layer extends into the rock along grain boundaries of the dolomite crystals (D). Soily accretions appear on top of the weathering layer at far left and top near edge of field. Back-scattered electron micrograph. Magnification 400×, width of field 0.26 mm. Boston, Museum of Fine Arts 1970.267. Photo: author.

marbles are shown in figures 9–14. The weathering layers found on many of the dolomitic marbles examined for this article (for example, figs. 9–12) consisted almost entirely of calcium carbonate, which appeared fine-grained and compact, sometimes with irregular porosity that took the form of minute branching "tunnels" (fig. 9; this same sample is shown at lower magnifications in fig. 1). The maximum thicknesses varied from about 0.08–0.14 mm. In all of these illustrations, the calcitic layer is a lighter gray than the dolomitic rock substrate, since calcium carbonate has a higher average atomic number than calcium magnesium carbonate.

Within the calcitic layers, often no element other than calcium was detected at a significant level. In some instances, the calcitic layer penetrates along grain boundaries some distance into the rock, outlining dolomite grains (figs. 10, 11a–b, 12a–b). These calcitic layers could very well represent the results of a dedolomitization process. They are clearly different in appearance and composition from the layers observed on calcitic marbles, which usually appeared to be somewhat inhomogeneous mixtures of soil minerals and calcite fragments, perhaps impregnated with reprecipitated fine-grained calcium carbonate.

There are sometimes regions within the calcium carbonate layers that are rich in aluminum and silicon, with scattered grains of calcite or dolomite probably dissociated from the rock surface (figs. 12a–b, 13a–b). These areas are quite similar to the layers that were typically seen on calcitic marbles. Often a "soily" layer occurs over the calcitic layer.

The boundaries between the dolomite and the

FIG. 11a

Thin section of Roman roundel with portraits, mid-second century A.D., showing a calcitic weathering layer (C) on dolomitic marble, with some soily accretions on the calcitic layer. Back-scattered electron micrograph. Magnification 250×, width of field 0.42 mm. Boston, Museum of Fine Arts 1980.212. Photos: author.

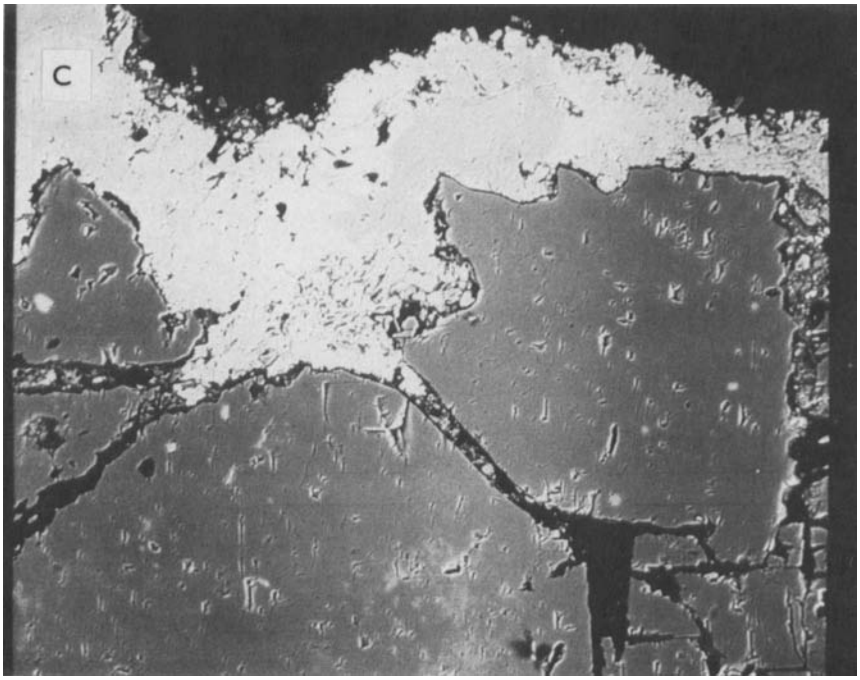
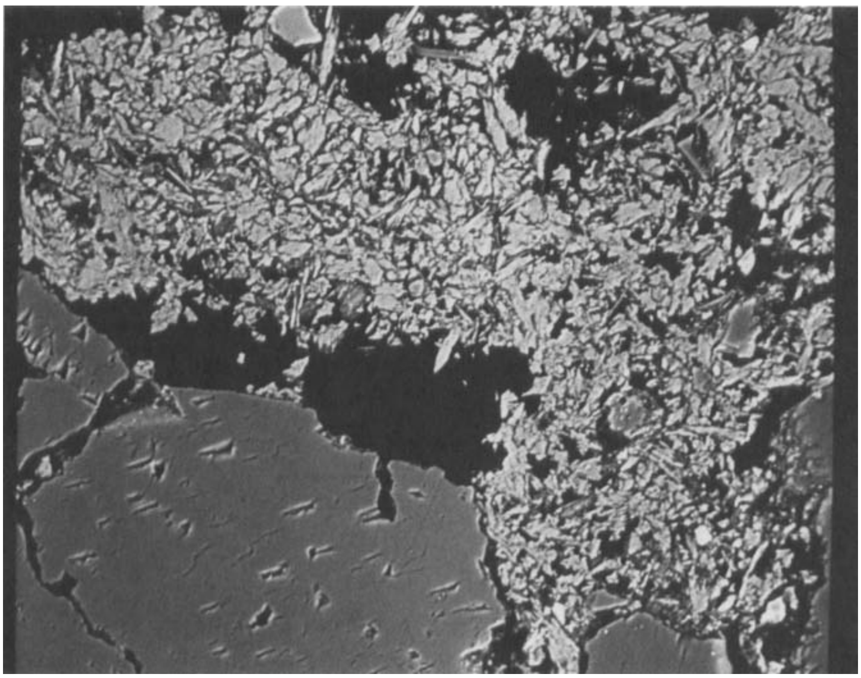
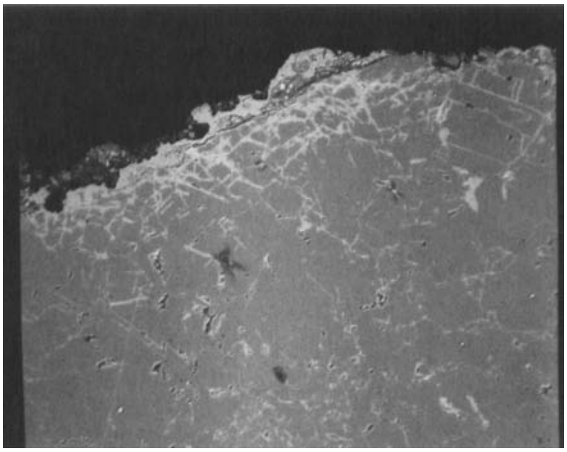


FIG. 11b

Detail of figure 11a showing the appearance of calcite in parts of the weathering layer; in other places, it is more compact. Magnification 500×, width of field 0.21 mm.





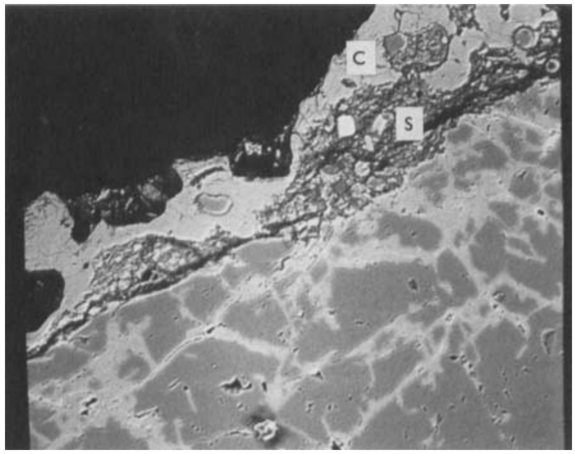
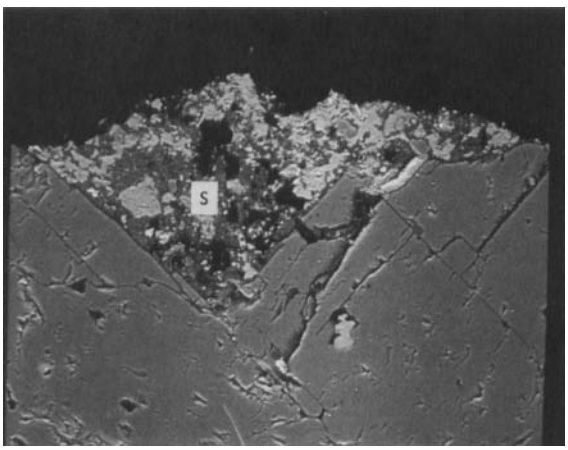


FIG. 12a

Thin section of Greek three-sided relief, about 470–450 B.C., showing compact calcitic weathering layer on dolomitic marble; pockets that contain clays occur in the weathering layer and soily accretions over the layer in places. Calcite (lighter gray) penetrates along grain boundaries of the dolomite crystals (darker gray) about 0.3 mm into the stone. Back-scattered electron micrograph. Magnification 70×, width of field 1.06 mm. Boston, Museum of Fine Arts 08.205. Photos: author.

FIG. 12b

Detail of figure 12a showing one of the pockets (S) within the calcitic layer (C) that is rich in aluminum and silicon. Magnification 290×, width of field 0.26 mm.



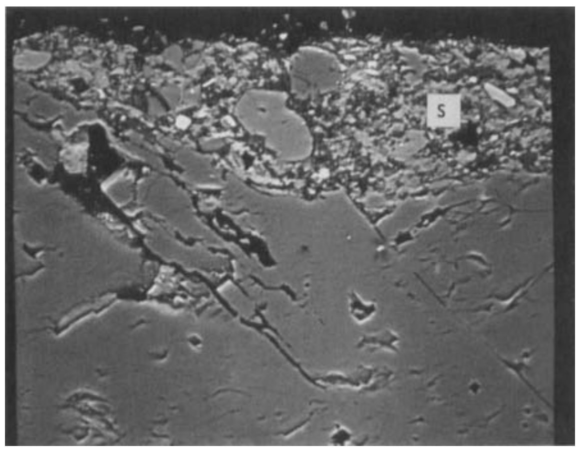


FIG. 13a

Thin section of Graeco-Roman funerary urn of Cassius, about A.D. 200, with pocket of a calcium-rich weathering layer (S) on dolomitic marble. The layer contains grains of calcite, small iron oxide(s), and potassium feldspar(?) in a finer matrix of clay and calcium carbonate. Back-scattered electron micrograph. Magnification 330×, width of field 0.23 mm. Boston, Museum of Fine Arts 1972.356. Photos: author.

FIG. 13b

Detail of figure 13a showing larger grains of several minerals in the finer-grained clay and calcium carbonate matrix of the weathering layer (S). Magnification 585×, width of field 0.13 mm.

calcitic weathering layers are generally sharp, even in the extensions into the grain boundaries. Quantitative microprobe analyses of two of the dolomitic marbles suggested that there is a very thin transition layer slightly depleted of magnesium at the surface of the dolomite, just below the calcitic weathering layer in one of the samples but not in the other.[14]

Two dolomitic marbles contained "soily" weathering layers similar to those observed on calcitic marbles (figs. 13a–b, 14a–b). In neither sample was a calcitic layer observed.[15]

APPLICATION OF WEATHERING LAYERS IN AUTHENTICATION STUDIES

The value of the study of weathering layers with respect to questions of authenticity depends on the confidence with which one can answer two questions:

1. Should such layers always be present on old marble surfaces, assuming that no cleaning has taken place?
2. Can layers of similar appearance or composition be applied or induced in a convincing fashion?

William Young's empirical observations, based on the study of quite a number of samples, implied that the answer to the first question should generally be "yes." This should, however, be a qualified "yes," since among the relatively few samples studied for the present article, there were occasional instances where a substantial weathering layer appeared not to be present. It is often the case that the chip samples for preparation of a thin section cannot be taken from the sites one would ideally like to sample, and since the thickness of a weathering layer can vary considerably even within one thin section, it is of course possible that a weathering layer could be present in some places on a sculpture and not in others (perhaps including the place sampled). Certain treatments, particularly acid cleaning, could remove the soily layers we observed in many of our samples, and the possibility that a marble surface may have been cleaned should be kept in mind.

Could natural weathering layers of the types found on classical objects be expected on more recently carved surfaces? At the very recent end of the scale, apparently this is unlikely. We did not see a measurable weathering layer on a sample of a marble object that had been buried in the ground in the Boston area for nearly a century.[16] Young did not find such layers on modern sculptures or on (presumably modern) fakes he examined, but since it is very unlikely that any of these recent sculptures had ever been buried, they are not relevant to this question.

The "time frame" in which marble objects with substantial weathering layers of the types noted in this article could have been carved is as yet not well defined. Many circumstances combine to produce such layers: moist conditions, preferably with acidic water, would likely produce the most rapid alteration; drier conditions might result in little or no weathering of the kind we are discussing in this article. Perhaps some unusual environments might produce weathering layers in much shorter times than others, such as soils in moist limestone caves (as has been suggested from time to time). Because the nature of the environment in which a given marble object may have been buried is usually not known, it will likely not be possible to establish a very exact time frame for the majority of marble artifacts whose surfaces are covered by weathering layers. But examination of greater numbers of samples, including ones from objects of postclassical origin, will help better to define the general time frame for natural burial weathering layers.

The carving of fakes or reproductions of classical objects is a phenomenon of the Renaissance and later. Some late medieval and Renaissance marble objects that have been examined in the Research Laboratory at the Museum of Fine Arts contained weathering layers similar in appearance to those on classical objects. This brings up the question of whether early (e.g., Renaissance) reproductions or forgeries of classical objects could readily be distinguished from genuine ancient objects on the basis of the presence of a substantial weathering layer.

Can layers of similar appearance of composition to those found on genuine classical marble objects be applied or induced convincingly? As noted above, induction of a convincing weathering layer by short-term burial alone seems unlikely. Staining of a fresh marble surface could be induced, but such a procedure would not produce any weathering layer. Some of the layers observed on calcitic and some dolomitic marbles clearly contained substantial amounts of soil components such as clays and micas. An applied soil patina prepared from an artist's earth pigment would be more homogeneous than most of the genuine soily layers we observed. If applied with a medium, the medium would be susceptible to solvents and could be detected by a variety of analytical procedures. Actual soil could also be applied, but it presumably would lack the firm attachment to the surface of the natural layer. One can envision the application of a soily layer that could conceivably resemble an actual "patina" quite closely so far as mineral components and matrix are concerned, although the apparent firm attachment of the genuine "patinas" to the stone surface (probably by reprecipitated calcite) would be more difficult to recreate.[17]

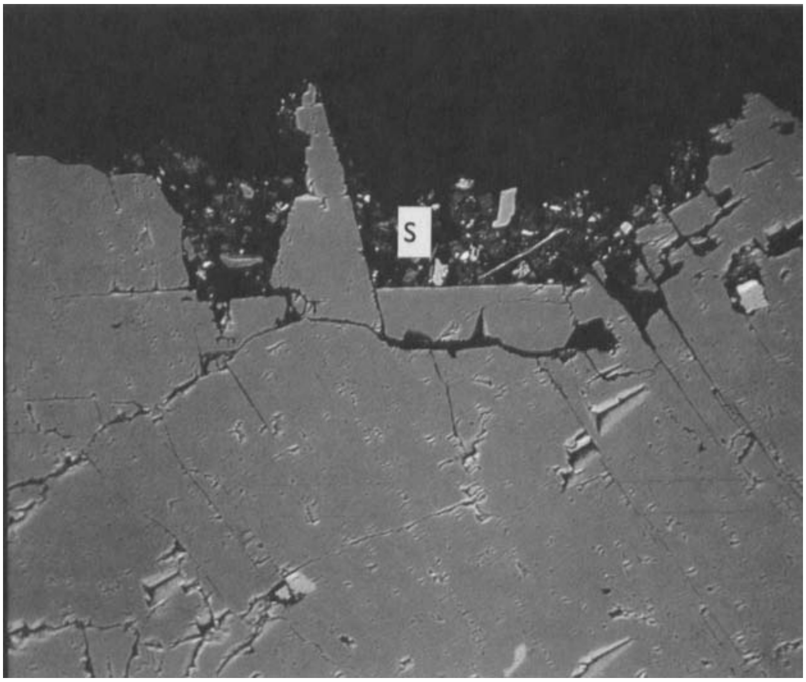


FIG. 14a

Thin section of the "Ludovisi Throne," Greek, about 470–450 B.C. showing patches of a soily weathering layer (S) on dolomitic marble. Back-scattered electron micrograph. Magnification 200×, width of field 0.53 mm. Rome, Museo Nazionale Romano 8570. Photos: author.

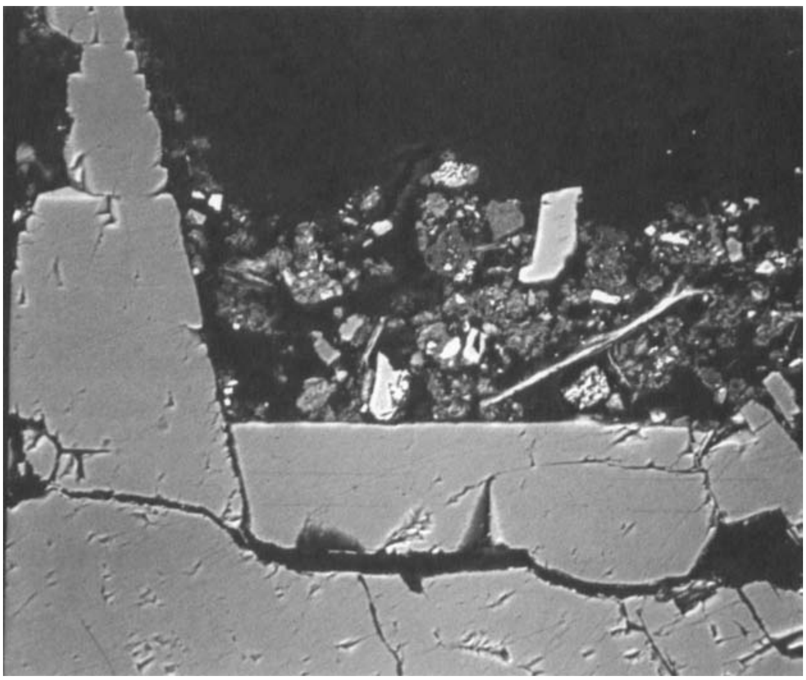


FIG. 14b

Detail of figure 14a showing grains of quartz, calcite, a splintery flake of chlorite, and some smaller grains of mica and amphibole or pyroxene(?) in the fine matrix of clay. Magnification 400×, width of field 0.26 mm.

Some of the samples examined for this article showed erosion of the marble well into the grain boundaries, while others showed virtually no such solution. Although this could be an artifact of sampling (a given sample, after all, only examines one small plane of a cross-section, which itself represents a very minute part of the overall altered or weathered surface), it does not appear that extensive solution into the rock substrate is necessarily a part of the weathering process on all old marble objects. Whether such erosion as was observed can be duplicated by acid treatment, for example, requires further research.

The compact calcitic layers observed on some of the dolomitic marbles, particularly those accompanied by growth of the layer along grain boundaries into the rock, seem very unlikely to be reproducible artificially. Finding this type of layer on a dolomitic marble would seem to be a very good indication of substantial age for a surface.

While William Young's experience in looking at samples from objects, both old, new, and fake, indicates the value of weathering layers as a piece of evidence in the authentication of marble artifacts, there is much additional work that could be carried out to further refine the technique. The electron beam microprobe, an instrument now widely used in many studies of the materials of works of art, provides more specific compositional and structural information than examination by petrographic microscopy alone, and given its relatively ready accessibility it can be a part of many studies that involve weathering layers. There are questions that still need to be answered regarding the nature of the weathering or alteration process and laboratory recreation of "patinas" imitating genuine alteration layers.

Museum of Fine Arts
BOSTON

Notes

1 W. J. Young and B. Ashmole, "The Boston Relief and the Ludovisi Throne," *BMFA* 66 (1968), pp. 124–166.

2 Photomicrographs of some of these samples were published in Young and Ashmole (note 1) and in E. J. Hipkiss, W. J. Young, and G. H. Edgell, "A Modified Tomb Monument of the Italian Renaissance," *BMFA* 35 (1937), pp. 83–90.

3 Young and Ashmole (note 1), p. 147.

4 For microprobe examination the samples were mounted with epoxy on petrographic slides, ground and polished with the usual series of sandpapers and polishing compounds, and carbon-coated. The samples were examined in a Cameca MBX microprobe (Department of Earth Sciences, Harvard University). Qualitative analyses of weathering layers and inclusions in these layers were carried out by energy-dispersive X-ray fluorescence. Areas analyzed can be as small as approximately one micrometer.

5 Among the many general texts that discuss rock and mineral weathering is D. F. Ritter, *Process Geomorpholy* (Dubuque, Iowa, 1978), pp. 79–136.

6 The *CRC Handbook of Chemistry and Physics* (Boca Raton, Fla., 1980), p. B-87, gives the solubility of calcite at 25 degrees C as 0.014 g/l. Calculated from the solubility product (K_{sp}) of $10^{-8.35}$ at 25 degrees C, the solubility is 0.01 g/l. The K_{sp} value used is from K. Krauskopf, *Introduction to Geochemistry* (New York, 1967), p. 651.

7 The solubility of calcite in buffered water was calculated from the solubility product of calcite and the equilibrium constant for carbonic acid at 25 degrees C, using varying hydronium ion concentrations.

8 One of the many articles that may be cited on marble weathering in polluted environments is J. J. Feddema and T. C. Meierding, "Marble Weathering and Air Pollution in Philadelphia," *Atmospheric Environment* 21 (1987), pp. 143–157. Calculated recession rates for several cities are summarized in that article.

9 J. Thimme and J. Riederer, "Sinteruntersuchungen an Marmorobjekten," *AA*, 1969, pp. 89–105.

10 N. Herz, "Classical Marble Quarries of Thasos," in G. A. Wagner, ed., *Antike Edel- und Buntmetallgewinnung auf Thasos* (Heidelberg, forthcoming).

11 D. Cordischi, D. Monna, and A. L. Segre, "ESR Analysis of Marble Samples from Mediterranean Quarries of Archaeological Interest," *Archaeometry* 25.1 (1983), pp. 68–76. The same authors found traces of dolomite in samples from Carrara and Ephesos. Their results for Thasos are confusing, since they report nearly pure dolomitic marble at Limani (near the modern town of Thasos) and calcitic marble from Aliki and Vathy, whereas Herz's review (note 10) of the geology of Thasos shows that the dolomitic marbles outcrop near Cape Vathy, while marble from the other two areas should be calcitic. Sources of calcitic and dolomitic marble on Thasos were previously noted in J. Herrmann and J.-P. Sodini, "Exportations de marbre thasien à l'époque paléochrétienne: Le cas des chapiteaux ioniques," *BCH* 101 (1977), pp. 510–511, based on analyses carried out by L. van Zelst on samples collected by John Herrmann.

12 Solubility of dolomite is not as well known as that of calcite. The *CRC Handbook* (note 6) reports its solubility as 0.032 g/l at 18 degrees C. Using 2×10^{-17} as an estimate of the K_{sp} for dolomite (see K. J. Hsu, "Chemistry of Dolomite Formation," in G. V. Chilingar, H. J. Bissell and R. W. Fairbridge, eds., *Developments in Sedimentology*, vol. 9b [New York, 1967], pp. 184–189), solubility should be approximately 0.01 g/l.

13 K. de Groot, "Experimental Dedolomitization," *Journal of Sedimentary Petrology* 37 (1967), pp. 1216–1220.

14 Quantitative analyses for calcium and magnesium were carried out by wavelength-dispersive X-ray fluorescence, using carbonate standards; matrix corrections were carried out by the Bence-Albee method. The analyses were carried out with a raster about 2.5 micrometers wide in order to minimize sample damage during analysis, and thus differences that occur in areas

smaller than this would not be detected. In the sample from Museum of Fine Arts 1970.267 (fig. 10), at 5 micrometers from the surface calcium was 0.516 and magnesium 0.484 (calculated on the basis of one cation total); from 7–26 micrometers into the surface calcium averaged 0.505 ($\pm$0.003) and magnesium 0.495 ($\pm$0.003) for four separate analyses (standard deviations on the averages in parentheses), indicating about a 2% change in calcium from the surface to the interior. No such variation was found in the sample from Museum of Fine Arts 08.205 (figs. 12a–b).

15 Young and Ashmole (note 1) reported results of emission spectrographic analyses of "dirt" from the surface of the Ludovisi throne (figs. 14a–b), which they compared with a similar analysis of surface dirt from the Boston relief. The thin section illustrated in the present article was prepared from a sample remaining from that earlier study. The conclusion in that article was that the Ludovisi throne and the Boston relief were probably buried near one another in Rome (although the analyses showed some differences in the compositions of the surface "dirt"). The thin sections prepared for the present article show different types of weathering layers on the two objects and give no reason to conclude that the burial environments were similar. This is one example of the additional information that microprobe analysis of weathering layers and inclusions can provide in the study of related objects that are suspected to have been in similar or identical burial environments.

16 Three samples from two objects in the collection of the Isabella Stewart Gardner Museum, Boston, were examined. One was from a part of an object that had been buried at a shallow depth in the Italian garden of Mrs. Gardner's estate (Green Hill) in Brookline, Massachusetts, probably continuously for at least ninety years. Although the sample showed extensive erosion of the surface, it contained no measurable weathering layer. I thank the Gardner Museum for permission to sample these objects.

17 A tomb attributed to the fifteenth-century Italian sculptor Mino da Fiesole was the subject of an early article by Young (see note 2). In several thin sections, Young noted a weathering layer that appeared quite similar to those he observed on classical objects. On the basis of this and other evidence, he concluded that the object was of Renaissance origin but had been partially recarved and restored. Shortly after this, an Italian forger, Alceo Dossena, announced that he had carved the object. On the basis of that proclamation and some stylistic peculiarities, the tomb has been in storage at the Museum of Fine Arts since the late 1930s. Dossena apparently had methods of achieving "time-staining" of his freshly carved marble surfaces (see A. F. Cochrane, "The Mystery of Mino's Tomb," *Harpers Magazine* [July 1938], pp. 137–147), but Young's samples appear to show distinct layers and not merely staining near the surface. We plan to prepare new samples of the "weathering layers" on this object for microprobe analysis, but have not completed this at the time of writing.

Ancient Greek and Roman Marble Sculpture: Authentication, Weathering, and Provenance Determinations

Stanley V. Margolis and William Showers

Establishing methods to check authenticity and age of marble and other stone sculptures and artifacts has long been an aim of researchers in art history, archaeology, and conservation. Information on style and art historical context is important in establishing authenticity, but such information can frequently be subject to controversy and conflicting opinions and interpretations. Geochemical and petrographic techniques similar to those used in geological investigations of rock weathering and mineral alterations can be used in studies of ancient marble as well as in provenance and source determinations.

The formation of "patina" on marble and other stone artifacts, along with other diagnostic surface features and alteration layers, has been used as an indication of antiquity.[1] The manifestation of such features, however, is a function of crystal size, mineralogy, rock type, and weathering history, as well as restoration and cleaning techniques previously used on the object. Therefore these features cannot be quantitatively used as indicators of absolute age. In addition, one scientific criterion by itself can seldom be considered conclusive proof of authenticity. Comparisons with weathering crusts from marble sculptures and ancient quarries of known antiquity may, however, be used to determine relative age, as well as to establish criteria for natural weathering.

One can also question whether these weathering features can be produced by artificial means, using present-day technology. Weathering features include surface encrustations of minerals such as iron and manganese oxides, clays, gypsum, silica, calcium carbonate and calcium oxalate, and "scialbatura,"[2] as well as a variety of organic substances.

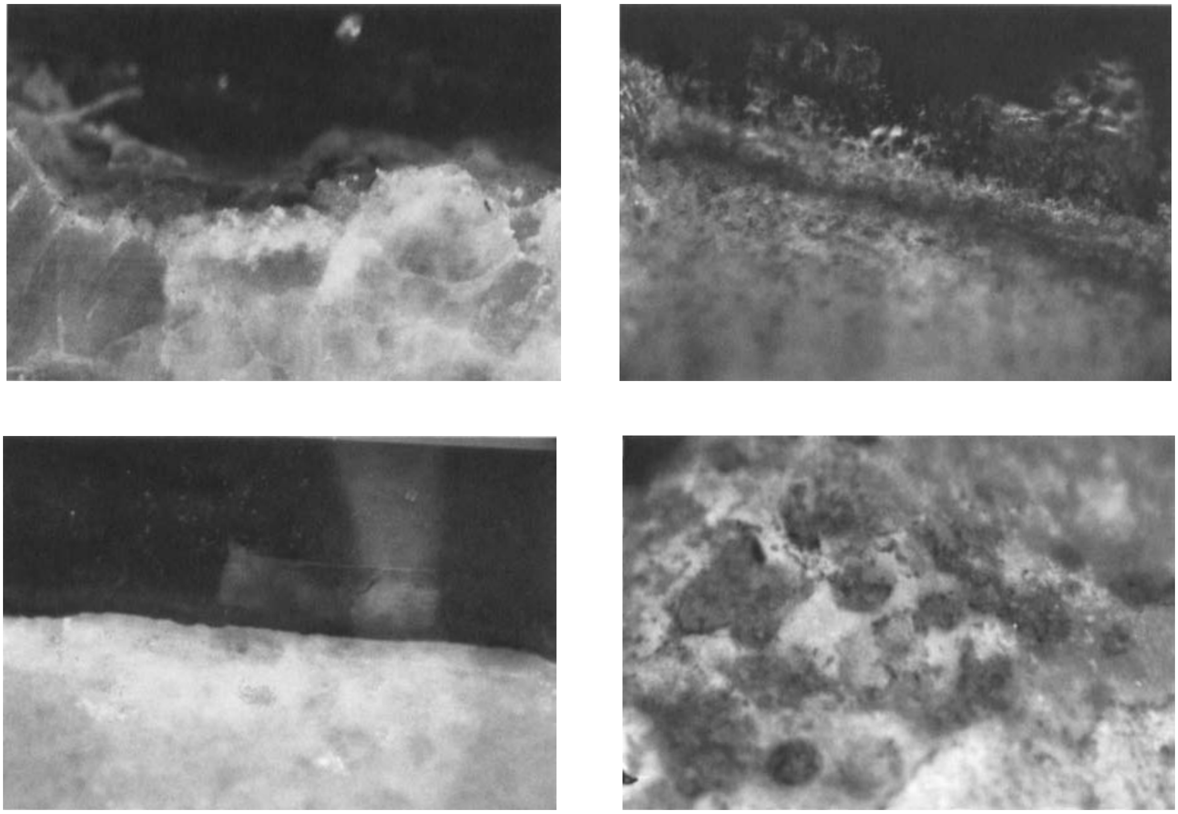
Many previous investigations have used ultraviolet examination to identify ancient surfaces, the theory being that ancient surfaces fluoresce amber, sometimes mottled with purple, while fresh or modern surfaces have a light purple fluorescence with no amber coloration.[3] Exceptions to the above model, however, have been found in marbles of varying mineralogy, crystal structure, trace-element chemistry, and weathering history. The exact causes for the fluorescence patterns and colors have not been related to the above parameters. This technique will continue to be useful in determining joining surfaces, repairs, and modern reconstructions, but for authentication it should be used in conjunction with other more quantitative geochemical techniques.

OXYGEN AND CARBON ISOTOPE ANALYSES OF MARBLE SCULPTURE

Oxygen and carbon isotopes have been used extensively for studies of provenance of marble statues by relating them to the isotopic compositions of rocks from ancient and modern quarries.[4] This technique has been useful in defining the source of marble and therefore in identifying obvious forgeries made from marble derived from modern quarries or, in some cases, from improbable source rocks. Forgers could, however, select the appropriate marble, or rework ancient artifacts or building stones from appropriate sources. Isotopic variations within modern marble quarries can be great, and in some cases discrimination between marble sources can be quite difficult because of overlapping fields of data. Besides, there may have existed many now unknown ancient quarries that have been worked until all the marble was gone, making it impossible to identify all possible ancient marble sources.

The development of modern isotope ratio micro-mass spectrometers has now made it possible isotopically to analyze extremely small (less than 0.02 mg) samples of marble.[5] This allows sampling of antiquities without causing significant damage to the object, and it permits studies of isotopic compositions of a wide variety of samples of marble type and age. It is now also possible to take samples from a profile across weathering layers to the fresh interior of a presumed ancient marble piece to determine whether the presence of a natural isotopic alteration signature is consistent with weathering over a long period of time.[6] Alternatively, the data could indicate disequilibrium caused by artificial leaching, etching, or other chemical alterations. These techniques, together with electron microprobe analysis of trace elements and PIXE permit the identification of chemical weathering and alteration gradients in the marbles.

The combination of these techniques can be an effective way of determining the authenticity and provenance of ancient works of art in stone; however, they do require that small samples be taken from diagnostic areas of each piece. Although the samples are small and can be taken from areas that do not detract from the artistic value of the object, nor damage it in any way, most curators are understandably reluctant to have such analyses performed. Exceptions occur when the authenticity of an object has been seriously questioned, and when such tests would help to either resolve the controversy or aid in



FIGS. 1–4

Iron staining and alteration layer in naturally occurring marble outcrop. Transmitted light micrographs. Magnification 210×. Samples from California (1, 2), Paros, Greece (3), and Carrara, Italy (4). Photos: author.

a decision to purchase an object. The technology to perform these analyses on micro-samples has only been developed in the last decade. Few laboratories have the necessary instrumentation available and not all the laboratories that do have scientists trained and experienced in the interpretation of geochemical data on weathering processes of these types of rock. This paper will outline the criteria that can be used in such studies.

PROCEDURES

We have been conducting a long-term project to investigate the weathering characteristics of a variety of marble types as part of a collaborative effort with the J. Paul Getty Museum and the Getty Conservation Institute. Samples of ancient Greek and Roman marble statues were examined from the Getty Museum, the Virginia Museum of Fine Arts, and the M. H. De Young Museum in San Francisco. The study focuses on examining weathering crusts and surficial deposits on a variety of ancient marble sculptures, ranging from Early Cycladic through early Roman Imperial date, primarily from the collections of the Getty Museum (Table 1). We also examined samples from ancient Greek quarries as well as outcroppings of weathered marble from Greece, Italy, and the United States. In addition, modern garden sculptures from Southern California were sampled and examined as a basis for comparison with the ancient pieces. Laboratory experiments were conducted on a variety of different calcitic and dolomitic marbles in

Table 1. Marble weathering study. Objects in the J. Paul Getty Museum

	^{13}C	^{18}O	**Provenance**	**Crust**	**Surface**	**Composition**
1. CALCITE	1.861	−1.649	Doliana, Hymettos, similar to Attic relief	Etched, thin	Honeycombed	Gypsum, clay, Fe, Zn, Si
Comments: Mn in pits, natural solution, loose dirt on surface						
83.AA.209 Approx. age A.D. 120						
2. CALCITE	1.512	−4.459	Afyon, Hymettos	None	High relief, etched, organics, dirt loose between grains	S, Si, Al
Comments: Loose dirt, no crust, etched, crumbly, loose tan silt						
76.AA.7 First century A.D.						
3. CALCITE	2.966	−3.195	Doliana	Well developed	Micritic, iron stained	Fe, Si, Ca
Comments: Deep solution pits, iron staining within, Mn crystals in matrix, good crust, chalky surface						
Marble outcrop, Greek mainland						
4. CALCITE	2.120	−3.248	Aphrodisias	Absent	Etched, gray, high relief	Ca, Si, organics
Comments: Coarse crystals, highly etched, no crust observed						
84.AA.11 Mazarine Venus, second century A.D.						
5. CALCITE	2.068	−6.226	Naxos (Apollonas)	Thick	Chalky, tan	Fe, gypsum, Si, clay
Comments: Coarse crystals, good tan crust, naturally irregular surface, some solutional features						
72.AA.94 120–130 A.D.						
6. CALCITE	2.161	−1.685	Similar to 1	None	Fungal filaments, dirt	Organics
Comments: Etched surface, loose dirt						
Modern guard lions at gate to ranch						
7. CALCITE	1.880	−5.352	Naxos, Ephesos	Thin	Micritic, powdery, iron stained	Fe, Si
Comments: Dense, fine marble, tan, fine powdery crust						
Marble outcrop, mainland Greece						
8. CALCITE	2.520	−0.475	Carrara?	Very thin	Fresh, with loose tan and red powder	Fe, Ca, Si
Comments: Iron stain extends slightly below surface						
79.AA.18 Akroterion, 320 B.C.						
9. CALCITE	1.163	−4.561	Afyon, Hymettos	Thin	Granular, tan, crumbles easily	Fe, Ca, Si
Comments: Thin fine crust, tan to gray, chalky						
76.AA.7 First century A.D.						

10. Fresh marble	0.372	−8.439	Unknown	Thick, continuous iron stain	Beige color, fine-grained	Fe, Ca, Si
CALCITE						
Crust	0.019	−8.308				
Crust δ	−0.353	000				
Comments: Iron and Mn stain, thick chalky crust						
71.AA.121 Stele, fourth century B.C.						
11.	1.809	−3.834	Aphrodisias	Freshly etched	Crumbly	Ca, Fe
CALCITE						
Comments: Deeply etched, high relief, chalky infillings, no crust, slight tan color on surface only, coarse crystals						
73.AA.32 Zeus, second century A.D.						
12.	2.484	−6.096	Naxos (Apollonas)	Thick, well developed	Roots and root casts, tan color	Clay, Si, Ca, S, Al, K, Fe
CALCITE						
Comments: Dense marble, dark tan crust, irregular surface, clay and iron on weathered surface						
72.AA.126 Niobid, first century B.C.						
13.	1.077	−4.235	Aphrodisias, Hymettos	Thick, complete	Tan, fine-grained	Gypsum, Si
CALCITE						
Comments: Dense marble, dark tan crust, rough surface						
72.AA.153 Female figure, early third century A.D.						
14.	2.084	−1.592	Similar to 1	None	Heavily etched, loose dirt, crumbles, large crystals	Organics
CALCITE						
Comments: Coarse, crumbly surface, dirt on surface only						
Modern Garden Sculpture						
15.	−1.516	−4.082	Hymettos, Aphrodisias	Thin	Fine-grained, powdery surface	Fe, K, Si
CALCITE						
Comments: Dense, fresh marble, loose surficial dirt						
Modern Garden Sculpture						

order to simulate natural weathering conditions and to duplicate naturally occurring surface patinas on classical marbles.

Drill-cores have been taken with a diamond core drill from diagnostic areas of each piece in the sample discussed above. In addition, available chips, surface encrustations, and other deposits have been analyzed. Acetate peel replicas have been taken and examined where it was not possible to take core samples. Detailed light microscopic examinations were performed prior to the sampling in order to assess the weathering and petrographic character of the marbles, and thin sections were examined in a similar manner.

Each core was approximately 0.5 cm in diameter and about 1 cm long and included a weathered outer surface. The marble drilling slurry was collected from the cooling water, and care was taken not to contaminate these samples in order that they could be used for chemical and mineralogical analytical purposes. The cores were cut longitudinally with a diamond saw, and polished thin sections were prepared for electron microscopic, electron microprobe, and petrographic study. Incident-plane, polarized, color micrographs were taken of each polished section prior to carbon coating for microprobe analysis. X-ray diffraction analyses were performed on both the dried drilling slurry and on ground powders from the core samples. These same powders were used for X-ray fluorescence trace-element analysis and PIXE analyses at the Crocker Nuclear Laboratory, University of California, Davis, in collaboration with Dr. Tom Cahill and Dr. Bruce Kusko. Oxygen and carbon stable isotope determinations were performed at North Carolina State University by Dr. Bill Showers. Standard geochemical techniques were used for all analyses described above.

RESULTS

Marble quarry samples exhibit a greater range of trace elements in the outer 5 mm of weathering crust than in their fresh interior (Table 2).[7] This data can be used to characterize chemical signatures of weathering crusts to compare them with ancient artifacts, and it is also useful for provenance determinations since it is relatively nondestructive. Sr/Ca ratios can be calculated from this data, and the results compare favorably with those of Lazzarini et al.[8] for Parian, Naxian, Hymettian, and Carrara marbles (Table 3). Stable isotope results from ancient quarries, outcrops, and ancient sculpture show progressive isotopic depletions in their surficial deposits, in comparison with fresh, unweathered marble (Table 4).

Samples from ancient sculpture, outcrops, and quarries exhibit varying thicknesses of weathering layers (figs. 1–4). The processes that have caused the weathering layer are similar to those that produce the "patina" typical of ancient marble statues. Chemical action – from exposure to atmospheric, meteoric, ground- and soil water – is the principal cause of alteration and decay of marble and limestone. This is usually enhanced by organic activity, physical weathering, fracturing, and temperature variations. Atmospheric waters contain trace amounts of carbon dioxide and hydrochloric and sulfuric acids, especially in populated areas. These combine with humic acids in the soils to dissolve, leach, and recrystallize calcium carbonate. Cracks and fractures enhance weathering as they allow the penetration of both air and water into the marble. The degree of alteration is a function of the composition and texture of the marble and its weathering and burial history; the chemistry and mineralogy of soils and waters it is exposed to are also important. Encrustations and stains can either come from precipitation in water and soils in contact with the marble or from leaching out of impurities from within the marble, the exact nature and source of which

Table 2. PIXE analysis (XPIX) summary table, marble standards. Amounts normalized to Ca = 1,000, no matrix corrections. 1 mm proton spot, 1 min. exposure, no filter. Outer layer = 5 mm spot in outer layer, 5 min. exposure, no filter. * = below detectable limits. Analyses performed at Crocker Nuclear Laboratory by Tom Gill and Bruce Kusko

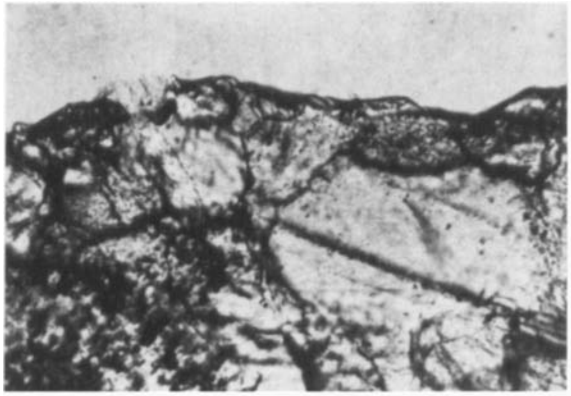
Sample	Ca	Hg	Fe	Mn	Si	Zn	Al	Ti	P	S	Ni	Sr	V	Cr	Ru	Cd	Co	Cu
Parian marble, ancient quarry																		
5 mm spot, 5 min. exposure																		
Outer layer	1,000	3.7	7.9	4.8	2.4	5.0	6.4	0.4	40.3	10.7	0.6	96.7	2.4	7.4	3.6	*	*	*
1 mm spot, 1 min. exposure																		
0–2 mm depth	1,000	*	0.2	*	2.2	*	5.7	*	37.0	0.9	*	*	*	*	*	*	*	*
Average																		
0.5 cm–1 cm depth	1,000	*	*	*	*	*	5.6	*	37.8	1.2	*	*	*	*	*	*	*	*
Pentelic marble, ancient quarry																		
5 mm spot, 5 min. exposure																		
Outer layer	1,000	*	62.1	10.4	2.7	*	7.2	0.4	41.0	10.1	*	70.3	1.3	5.5	*	8.8	*	3.5
1 mm spot, 1 min. exposure																		
0–2 mm depth	1,000	*	0.7	*	2.2	*	5.7	*	37.0	0.9	*	*	*	*	*	*	*	*
0.5 cm depth	1,000	*	1.1	*	2.2	*	5.6	*	37.5	1.0	*	*	*	*	*	*	*	*
1 cm depth	1,000	*	0.4	*	2.2	*	5.6	*	38.1	1.3	*	*	*	*	*	*	*	*
Carrara marble, weathered outcrop																		
5 mm spot, 5 min. exposure																		
Outer layer	1,000	2.9	17	11.3	*	6.2	6.5	0.4	37.9	10.2	0.6	144.5	3.5	10.5	*	*	1.9	2.0
1 mm spot, 1 min. exposure																		
Average of 3 spots from outer 1 cm	1,000	*	*	*	*	*	*	*	37.2	1.0	*	*	*	*	*	*	*	*

Table 3. Ca/Sr ratios for J. Paul Getty Museum marble pieces and standards. Data obtained from PIXE analysis, Table 1, and from Lazzarini et al. (1980)

Sample	Ca/Sr	Marble provenance
Parian marble	10.34	Ancient quarry
Pentelic marble	14.22	Ancient quarry
Carrara marble	6.92	Weathered surface
Cycladic Idol, M. H. de Young Museum	23.98	Naxian
Cycladic Seated Harpist, Virginia Museum of Fine Arts	10.70	Parian
UCD Carrara Standard	3.6	Modern statuary Carrara
Average of 9 Carrara marbles	7.21	3 modern Carrara quarries
Actual Carrara values	4.0, 4.6, 5.1, 6.4, 6.5, 7.2, 9.5, 10.4, 11.2	
Average of 4 Hymettian marbles	9.8	Mount Hymettos quarry
Actual Hymettian values	7.9, 10.3, 10.4, 10.9	
Average of 2 Pentelic marbles	13.85	Mount Pentelikon, Penesi quarry
Actual Pentelic values	13.7, 14.0	
Average of 4 Naxian marbles	21.8	Naxos, Kinidaros quarry
Actual Naxian values	15.1, 21.4, 22.0, 28.8	
Average of 5 Parian marbles	9.72	Paros quarries
Actual Parian values	7.6, 8.5, 9.9, 10.2, 12.2	

Table 4. Marble weathering study isotope data. All values vs. PDB isotope standard. After Margolis, Preusser, and Showers (1988)

Sample	$\delta^{13}C$	$\delta^{18}O$	Crust	Surface Composition
Thasian dolomite				
Ancient quarry, fresh	3.438	-4.200	Thick	Tan, Fe, Mn, stained
Hard crust	-0.129	-4.404		
δ D crust	-3.567	-0.204		
Soft surface crust	-1.829	-4.632		
δ D surface	-5.309	-0.432		
84.AA.13 grave stele				
Fresh marble	-1.100	-2.957		
Stele crust	-5.876	-6.169	Thick	Fe, Mn, Si, Ca, S
δ D fresh vs. crust	-4.776	-3.212		
Comments: Limonite, hematite in solution holes, deep iron staining				
71.AA.338 Aphrodite				
Fresh marble	0.948	-4.357		
Surface scrapings	0.444	-4.374	Thick	Si, Mn, Fe, Ti
δ D fresh vs. crust	-0.504	-0.017		
Comments: Dense, coarse marble, iron staining				
84.AA.60 Homer Estragos				
Fresh calcite	2.265	-5.312	Thin	Smooth, weathered Ca, Si, Al, Gypsum
Crust	1.938	-5.717		
δ D	-0.327	-0.405		
Comments: Irregular, naturally weathered surface, some solutional features				
Parian marble				
Ancient quarry, fresh	5.15	-2.95		
Soft surface crust	-5.05	-3.25	Thick	Weathered Fe, Ca, Si
Hard crust	-9.50	-5.10		
δ D fresh vs. soft crust	-10.20	-0.30		
δ D fresh vs. hard crust	-14.65	-2.15		
Parian marble				
Archaic statue, fresh	5.10	-3.05	Thick	Weathered Fe, Ca, Si
Soft surface crust	-5.11	-4.14		
Hard crust	-8.20	-4.60		
δ D fresh vs. soft crust	-10.21	-1.09		
δ D fresh vs. hard crust	-13.30	-1.55		



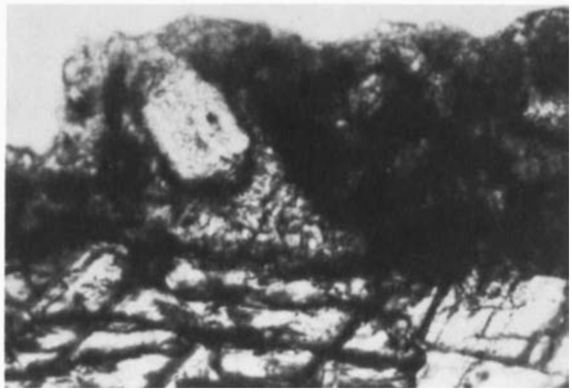



FIG. 5

Petrographic section of the surface of marble from a forgery of an Archaic Greek head. Note lack of weathering crust. Magnification 420×. Boston, Museum of Fine Arts F 10 (from Young and Ashmole, fig. 31).

FIG. 6

Petrographic section of Greek relief, about 470–460 B.C. Note dark micritic calcite crust on top of crystals. Magnification 420×. Boston, Museum of Fine Arts, Henry L. Pierce Fund 08.205 (from Young and Ashmole, fig. 32).

FIG. 7

Petrographic section of the surface of marble from a Greek sphinx, 530 B.C. Dark coating on top of clear crystals is crust. Magnification 420×. Boston, Museum of Fine Arts 40.576 (from Young and Ashmole, fig. 29).

FIG. 8

Petrographic section of marble surface from a Roman sarcophagus, about A.D. 150–200. Note dark calcite crust. Magnification 420×. Boston, Museum of Fine Arts 76.716 (from Young and Ashmole, fig. 30).

can be determined by electron microprobe analysis. In a dense, finely crystalline marble, such alteration is a slow process.

Young and Ashmole[9] presented evidence for this alteration layer by comparing thin sections of marbles of indisputable antiquity with a known nineteenth-century forgery (figs. 5–8). The weathering crust or altered layer is observed when a thin polished section is made of the surface layer and part of the unweathered interior (fig. 9). Young and Ashmole did not claim that this technique is a precise method of dating objects, but stated that "it has proven invaluable in helping to establish the authenticity of many works of art."

The differences in appearance between our photos of the weathering layer and the light micrographs are caused by the more advanced optical and electron microscopic techniques available now, which permit higher resolution and better definition of the microstructure of the alteration layer. Our analyses indicate that weathering crusts on marble sculpture appear to have formed in the following manner: Working of the marble by the sculptor, with chisel and punch, creates a thin layer of crystals in the outer layer that are "stunned," or fractured, which gives the surface a dull appearance, for the crystals lose their transparency. This fractured layer provides the conduits for penetration of water containing dissolved ions and suspended clays and promotes recrystallization of the calcite during weathering to form the thin layer of micrite (micro-crystalline calcite),

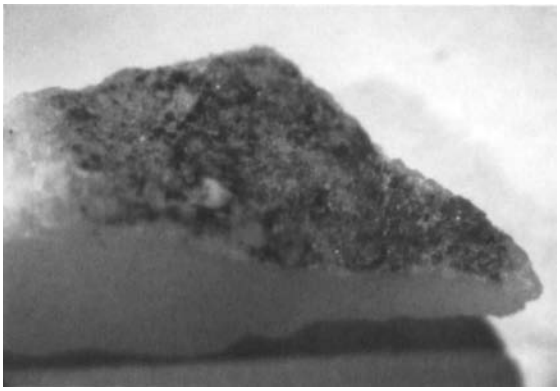
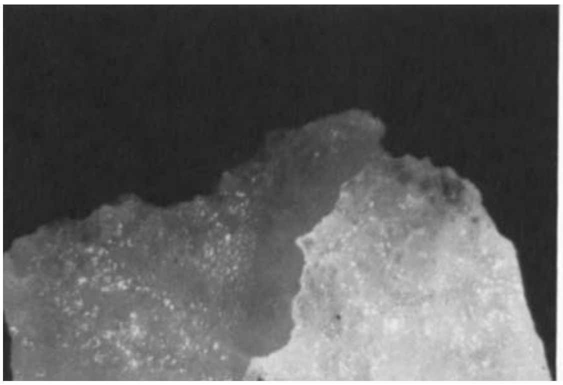


FIG. 9

Weathering layer on Classical Greek statue of Aphrodite. Light micrograph. Magnification 420×. Malibu, J. Paul Getty Museum 71.AA.338. Photo: author.



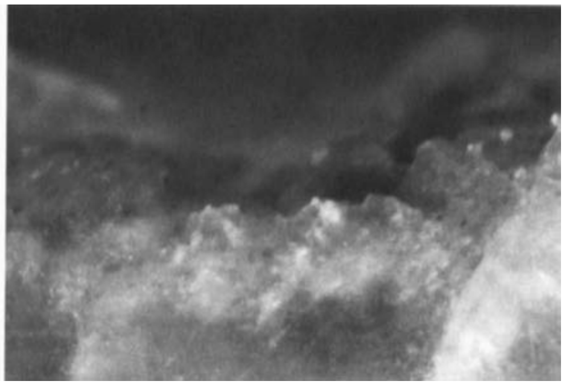


FIG. 10a

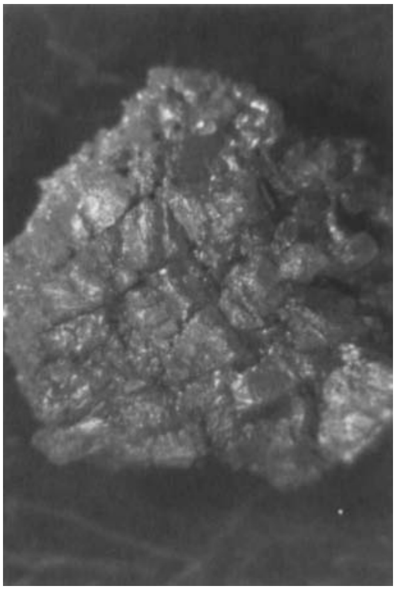
Red iron staining penetrating alteration layer in Archaic Greek marble statue. Fractured sections, light micrograph. Magnification 210×. Photos: author.

FIG. 10b

Same as figure 10a. Magnification 420×.

which differs from the underlying unfractured mosaic crystalline marble. This weathering/alteration surface progressively extends into the marble with increasing time of exposure to the elements or burial. The tan staining often observed on ancient statues and quarries (figs. 10a–b) is produced by the gradual infiltration of ground- or soil-water clays as well as penetration of dissolved and suspended iron oxide into the marble. Some of the iron staining may be the result of leaching and concentration of trace amounts of iron oxide minerals that are usually present in the fresh marble. Both are slow natural processes in dense marble, similar to what occurs in weathering of limestone and marble in outcrops and buried in soil horizons.

The weathering layer can be removed by acid cleaning treatment. Surfaces of marble so treated show fresh evidence of strong etching and dissolution (figs. 11a–b). If the iron oxide/clay mineral materials causing the tannish red stain were artificially introduced into the marble, then there would be a high concentration at the surface, with little or none penetrating into the dense matrix of the marble. Thin sections of naturally weathered marbles show most staining below the micrite alteration layer, continuing well into the matrix of the marble (figs. 12–13). This can only happen through slow, natural alteration; if the altered layer were artificially precipitated on the surface by chemical means, then it would not show the weathered tool marks frequently found on ancient sculpture. Careful examination of the



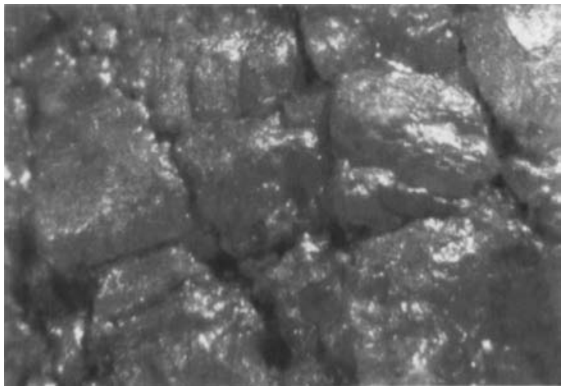


FIG. 11a

Heavy surficial etching on acid-cleaned Greek marble statue. Light micrograph. Magnification 420×. Photos: author.

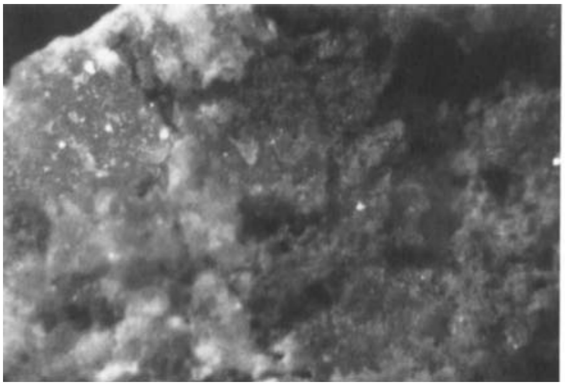
FIG. 11b

Same as figure 11a. Magnification 630×.

altered layer also reveals ghosts or relicts of the original crystal outlines, indicating slow in-situ alteration (fig. 14).

Naturally weathered calcitic marbles exhibit the following features:

1. A weathering crust or layer of alteration that is gradational between fresh marble in the interior and the original outside sculpted surface (figs. 15–16). This crust can vary in thickness between 10 μ and 10 mm. The thickness of the layer appears to be a function of age, although the intergranular porosity and crystal size are also important. Burial history and composition of local ground- and meteoric waters can also affect the structure and composition of the crust.
2. The weathering crust can exhibit gradients in trace elements such as Fe and Mn as well as clays and authigenic minerals that are natural soil and weathering products. These minerals extend into the interior of the marble and are not just loose surficial deposits.
3. The outside weathered surface, or "patina," consists of recrystallized calcite, clay minerals, zeolites, Fe and Mn oxides, calcium oxalate, and gypsum (figs. 15 and 16). Evidence for natural solution can also be found on crystals (fig. 17).



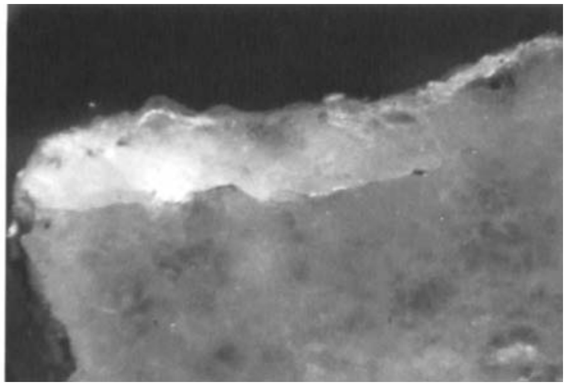


FIG. 12

Alteration layer with iron staining. Weathered Greek marble outcrop from Paros. Light micrograph. Magnification 525×. Photo: author.

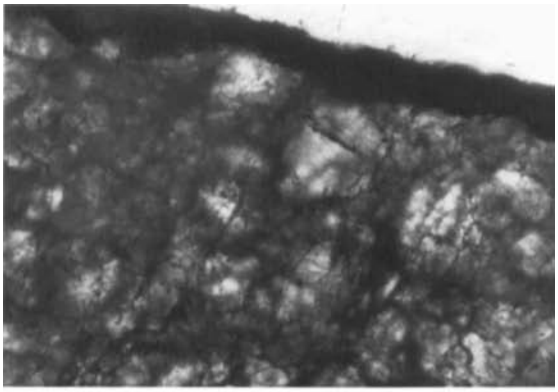
FIG. 13

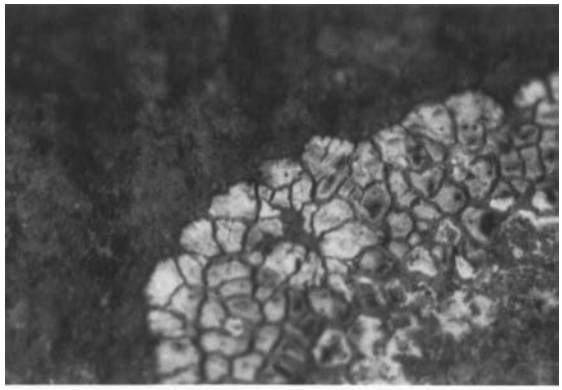
Surface of marble from Epikouros statue. Magnification 315×. Malibu, J. Paul Getty Museum 82.AA.77. Photo: author.

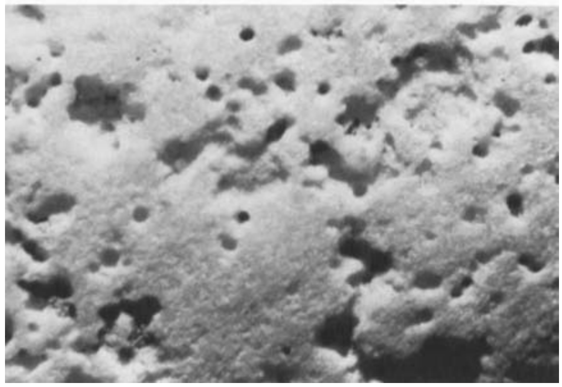
4. Oxygen and carbon isotope analyses of fresh marble from the interior of the stone, samples from the crustal alteration layer, and surficial carbonate deposits usually show a progressive depletion in $\delta^{13}C$ and $\delta^{18}O$ from inside to outside, reflecting recrystallization and micritization of the carbonate in surficial and soil weathering environments (Table 1). These differences, designated as δ D, vary with alteration crust thickness, water chemistry, and the source of nearby carbonate sedimentary rocks. The changes do not affect oxygen and carbon equally because of isotopic fractionation and thermodynamic considerations. The oxygen and carbon isotopes indicate that the calcite in the weathering crust originates both from the marble and from groundwater precipitation.

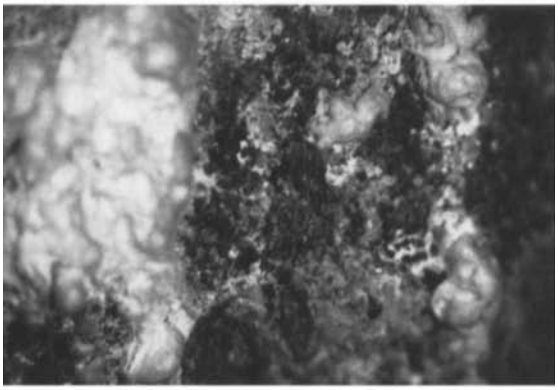
Dolomitic marbles are more resistant to weathering and, in general, do not exhibit the same features as calcitic marbles. Dolomites in some cases show a surface layer of calcite, which is believed to be the result of dedolomitization in natural weathering environments. This thin layer of calcite (fig. 18) has been found on outcrops of dolomitic marble, in ancient quarries, and on Archaic Greek statues.[10] Trace-element analyses by electron microprobe across these dedolomite layers indicate loss of Mg and formation of micritic calcite, along with addition of Fe, clay minerals, and Mn. This is responsible for the different "patina" on dolomitic marbles, compared to that found on statues sculpted from calcitic marble.

This difference in "patina" can often lead to false conclusions concerning the antiquity of a sculpture, since most workers in this area are more familiar with the "patina" found on calcitic marble. Not all dolomitic marbles have a surficial layer of calcite.









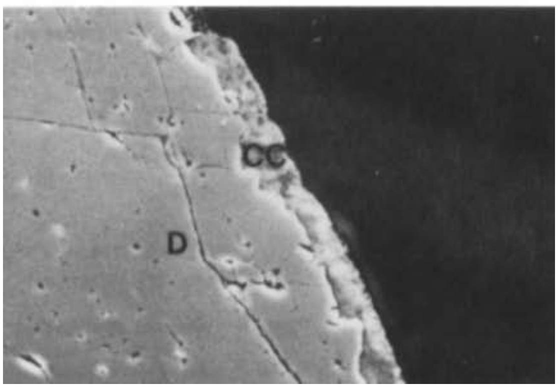


FIG. 14

Petrographic thin section of Cycladic idol showing alteration layer in polarized light and ghosts of crystal outlines. Light micrograph. Magnification 420×. Fine Arts Museum of San Francisco, M. F. de Young Museum, the William H. Nobel Bequest Fund 1981.42. Photo: author.

FIGS. 15–16

Surficial portions of marble quarry outcrop on mainland Greece near Athens showing lichen, iron staining, manganese oxide, and gypsum crusts. Light micrographs, reflected light. Magnification 105×. Photos: author.

FIG. 17

Surface of Carrara marble statue showing natural solution etching and pitting. Reflected light micrograph. Magnification 105×. Photo: author.

FIG. 18

Polished section of Archaic kouros showing layer of calcite developed by dedolomitization of original dolomite outer surface. Scanning electron micrograph. Magnification 2100×. Malibu, J. Paul Getty Museum 85.AA.40. Photo: author.

Some exhibit a crust of varying iron oxide content and evidence of surficial solution. Such layers are generally thinner than those found on calcitic marbles.

DISCUSSION

FIG. 19

Experimental dedolomitization apparatus simulating natural geochemical conditions using Thasian dolomite and solutions to replace Mg with Ca in dolomite structure. Solutions similar to soil and groundwaters were circulated through glass chamber containing dolomite crystals with the aim of inducing dedolomitization by replacing the Mg in dolomite with Ca to form calcite. After nine months of operation, no dedolomitization was produced, even at the microscopic level, but only chemical solution features, indicating that dedolomitization cannot be induced in relatively short time in the laboratory. Photo: author.

Laboratory experiments have been performed recently by us in an attempt to duplicate the features described above on calcitic and dolomitic marbles. In addition, several known fakes have been examined using the same techniques as those used to study the proven ancient pieces. Our preliminary results indicate that it is possible to produce a surface "patina" that to the unaided eye appears similar to those found on ancient marble pieces. However, closer scrutiny, using electron microprobe, electron microscope, and isotopic examination, reveals that in cross-section this artificial "patina" does not exhibit many of the features found on naturally weathered marble.

Attempts to simulate artificial dedolomitization in the laboratory (fig. 19) have so far failed to produce a calcite layer with geochemical characteristics similar to those found on ancient statues and outcrops.[11] Other experiments of accelerated marble weathering are currently in progress.

So far, these experiments cannot simulate the millennia of time that appear to be required to produce the features found on ancient marble surfaces, nor the variety of changing environmental conditions on and below the earth's surface. Biological activity, such as the action of endolithic algae, fungi, and lichens, as well as other plants and animals, also plays an important, but as yet poorly understood role in rock weathering. For instance, lichens are now believed to be important in the formation of "scialbatura" on marble outcrops and ancient artifacts.[12] Our observations also indicate that encrusting algae may contribute to the weathering of marbles and the formation of alteration crusts.

Naturally produced weathering crusts have been described on ancient marble sculpture and ancient outcrops from marble quarries, all of them similar in terms of their geochemical, isotopic, and petrographic characteristics. Their presence on a marble statue can be used as a means of evaluating its antiquity. In general, the longer the period of weathering, the greater the thickness of the weathering crust, and the greater the depletion in carbon and oxygen isotopic composition of the crust in comparison to the fresh marble below the crust. Not every sample of ancient marble, however, exhibits all the features of a typical weathering crust, due to the variability in texture and of the stone as well as the weathering history of each sample.

Some marble sculptures show evidence of

heavy surficial chemical etching, which could either be the result of acid cleaning – a common practice of conservators in the past – or prolonged natural dissolution by corrosive groundwaters. This etching would, in extreme cases, remove the weathering crust and along with it any evidence of antiquity. Careful examination can sometimes reveal remnants of the original weathering crust, which can then be evaluated using electron probe and isotopic techniques. In addition, acid cleaning can often be identified by the etching features it produces on the surfaces of calcite and dolomite crystals: slow, natural solution produces different features on crystal surfaces.

Analyses of representative weathering crusts from marble sculpture, using the techniques described above, can establish the presence of natural weathering features and their antiquity. In some cases, previous weathering history and conservation treatment limit the utility of such analyses. Traditional methods of authentication, including art historical, iconographic, and provenance determinations, would be most useful in these cases. In all cases, no one sample or method should be used to determine the authenticity of any piece of marble sculpture. Rather, as many methods as possible should be brought to bear on the determination of the authenticity of a marble sculpture, along with careful study and thorough evaluation of all the available data.

The data and observations presented in this paper indicate that not every piece examined exhibited all the criteria. Some showed heavy surficial etching, which had removed any evidence of a former weathering crust. In most cases it was possible to determine whether this chemical etching was from acid cleaning of the piece or from natural processes. However, in some cases this could not be determined from the small sample provided in this study: In those cases it would be necessary to examine further the entire piece in order to make a determination of its antiquity.

To sum up, in many cases a small representative sample of marble is sufficient to establish the presence of natural weathering features, and hence the authenticity of an ancient marble sculpture. In some cases, previous history or treatment make necessary further examination and study. In any case, no piece should be called a fake based on "blind" examination of one sample. It is recommended that the entire piece be carefully studied before any pronouncement on authenticity be made.

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ISBN 0-89236-174-3