ANALYSIS OF THE WEIGHT ASSEMBLAGES FROM THE LATE BRONZE AGE SHIPWRECKS AT ULUBURUN AND CAPE GELIDONYA, TURKEY

Volume I

A Dissertation

by

CEMALETTIN MUSTAFA PULAK

Submitted to the Office of Graduate Studies of Texas A&M University in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 1996

Major Subject: Anthropology
ANALYSIS OF THE WEIGHT ASSEMBLAGES FROM THE LATE BRONZE AGE SHIPWRECKS AT ULUBURUN AND CAPE GELIDONYA, TURKEY

Volume I

A Dissertation

by

CEMALETTIN MUSTAFA PULAK

Submitted to Texas A&M University in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Approved as to style and content by:

George F. Bass (Chair of Committee)

J. Richard Steffy (Member)

Steven M. Oberhelman (Member)

Frederick H. van Doorninck, Jr. (Member)

Sylvia A. Grider (Member)

Vaughn M. Bryant, Jr. (Head of Department)

December 1996

Major Subject: Anthropology
ABSTRACT

Analysis of the Weight Assemblages from the Late Bronze Age
Shipwrecks at Uluburun and Cape Gelidonya, Turkey. (December 1996)
Cemalettin Mustafa Pulak, B.S.; M.S., Bosphorous University, Istanbul; M.A., Texas
A&M University
Chair of Advisory Committee: Dr. George F. Bass

The assemblages of pan-balance weights recovered from the excavations of
Cape Gelidonya and Uluburun shipwrecks, in southern Turkey, comprise the largest
and most complete collection of Late Bronze Age pan-balance weights recovered from
single archaeological sites.

These assemblages owe much of their importance not only to the rare glimpse
they give us about the world of Bronze Age merchants and the consignments of
weighing implements they carried with them, but also because of the opportunity they
provide in allowing us to examine individual weights, weight sets, and pan balances
that were in concurrent use when each ship sank. Furthermore, by being able to
compare the two diachronic assemblages, separated in time from each other by about a
century, we are able to assess whether the weight standards were subject to a gradual
change or debasement of value over time.

Combining diverse information obtained from other archaeological excavations
with data obtained from the excavations at Uluburun and Cape Gelidonya, we are able
to make observations about local and long-distance trade and commercial patterns in
the Late Bronze Age Eastern Mediterranean. This analysis will also contribute to the
understanding of life and economic activities of the international trader during the
Bronze Age. From a macro perspective, analysis of the weight assemblages should
indicate some of the driving factors or economic necessities for standardization of
weights. An in-depth analysis of the weight collections from these Late Bronze Age
shipwrecks will draw together many sources of data, thereby offering new perspectives on the process of standardization of trade in the ancient world.
To my father who did not live to see his wish materialize, and to my mother who fervently continues to be the source of encouragement and support in my academic endeavors.
ACKNOWLEDGMENTS

A study of the weight assemblages from the Uluburun and Cape Gelidonya shipwrecks as a dissertation topic resulted after eliminating many other equally important artifact groups from the Uluburun shipwreck that were potential dissertation subjects. This seemingly difficult decision was aided by the fact that virtually every other artifact group is still in need of extensive cleaning, conservation, and restoration, which are tasks that will probably continue for years to come. This study was suggested to me as a dissertation subject by Professor George F. Bass and eagerly endorsed by Professor Frederick H. van Doorninck, Jr., after a long and involved process of elimination. Without their encouragement and support, this project could not have been conceived and executed. Professor Bass’s unwavering confidence in my abilities and unflagging support of my endeavors since we first met in 1975, when I was a graduate student in mechanical engineering volunteering as a field person, and he was the director of the Şeytan Deresi shipwreck excavation, and after my enrollment in the Nautical Archaeology Program at Texas A&M University in 1979, has been a constant source of inspiration that cannot be overstated. I have benefitted greatly also from the friendships and professional discourses on nautical archaeology matters with Professor van Doorninck and Professor Emeritus J. Richard Steffy. Their agreement to serve as committee members has also been a great encouragement in meeting graduation deadlines and other obligations that attend academic endeavors. For the opportunity to have studied under these three true pioneers of nautical archaeology, I feel most privileged and grateful. Heartfelt thanks and appreciation also go to Associate Professor Donny L. Hamilton, who not only has been a professor but a true friend. He has assisted me on untold occasions over the years on nearly every subject, not least of which was bailing me out of endless computer pitfalls and mishaps. Thanks are due also to Professor Steven M. Oberhelman, Associate Professor Sylvia A. Grider, and Assistant Professor Valerian Miranda for agreeing to
serve on my committee, and for a number of suggestions and corrections that have benefitted this study.

The field work upon which this study is based took 11 summers totaling more than 22,000 dives and over 6,300 hours of excavation time on one of the deepest shipwrecks ever excavated by conventional diving methods. For the volunteers and the staff of the Institute of Nautical Archaeology (INA) who have contributed years of their lives to make the Uluburun shipwreck excavation not only a success story, but also one of the most thoroughly excavated ancient shipwreck sites in the Mediterranean, I give sincere thanks. They are the true, unsung heroes of this project. They are too many to name here, but their contributions will be singly recognized and their names will take their deserved places in the final publication of the site. I am also most grateful to INA and its Board Members, Milan and Ray Siegfried, who have supported me with a fellowship during the excavation and study phases of the project.

In the course of researching, evaluating, and preparing this material, I have benefitted from the help, discussions, and constructive criticism of many. Their input has prevented me from making many errors of haste as I tried to complete the manuscript to meet the graduation deadline. I extend my special gratitude to my wife, Sema Pulak, who unselfishly and willingly huddled over her drafting table for months in order to produce in a record time all of the exquisite drawings of the weights presented here. Her toil over translations of convoluted materials in German and French has greatly helped me familiarize myself with some of the early publications, as well as more recent ones. To Dr. Michael Fitzgerald, whose phenomenal verbal skills not only made sure I wrote down what I intended, but also helped me avoid several embarrassing errors, and who virtually rewrote the detailed catalogs appended to this study that superseded my meager efforts; to Dr. Patricia Sibella, whose unending energy and drive, complemented by her word processing and drafting talents, and translation of many articles in Italian, French, and Spanish, without which none of this could be completed; to Jane Pannell and Claire Peachey, who spent countless hours
cleaning and conserving delicate objects shrouded in the ubiquitous underwater encrustation that rendered them unrecognizable; to Edward Rogers, who religiously kept extremely detailed notes of the last four seasons at Uluburun; and to Mark Smith, whose knack with computers condemned him to take thousands of solo measurements under water to produce a detailed contour map of the site, and which kept him chained to the computer to program and make initial runs of various statistical programs that form the backbone of this study, I extend my profound gratitude and heartfelt thanks. Claire Peachey has also identified the types of stones and minerals used to make the weights, Mark Smith took an independent set of mass and dimension measurements of each weight to complement and check the three sets I had taken over the last few years, and Mike Fitzgerald has restored many of the damaged weights with plasticine to calculate their original masses. These multi-talented, driven individuals, along with many other participants, have dealt with many other aspects of the site, but are singled out here because they spent the summer and fall of 1995 in the Bodrum Museum of Underwater archaeology to assist me with the bulk of the work that was needed to produce this study. Mike Fitzgerald and Patricia Sibella continued to contribute to the project until October of 1996; Maria Jacobsen, Sema Pulak, and Harun Özdaş pitched in with last minute proof readings of the text and helped prepare the dissertation for submission to Texas A&M University.

My thanks are due also to the director of the Bodrum Museum of Underwater Archaeology, Oğuz Alpözen and his able assistants, for generously allowing me and other members of the Uluburun team to use the conservation facilities in the museum and for giving us unlimited access to the material during our study.
# TABLE OF CONTENTS

## Volume I

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>INTRODUCTION: METHODOLOGICAL PROBLEMS, PRINCIPLES, AND PROCEDURES</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>The Identification of Near Eastern Balance Weights</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Materials Used in Near Eastern Balance Weights</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Shapes of Near Eastern Balance Weights</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Principles of Identifying Weights</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Ancient Weight Systems and Practical Factors, or Bases</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Factors Affecting the Determination of Mass Standards</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Current Condition of the Weight Specimens</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>The Balances</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Inaccuracies in the Duplication of Balance Weights</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>The Degree of Accuracy Acceptable to Those Who Used the Equipment</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Local and Geographical Variants of a Standard Unit of Mass</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Chronological Variations in the Mass Value of a Standard Unit of Mass</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Errors in Measuring and Recording Mass</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Principles of Investigation</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Statistical (Quantal) Analysis</td>
<td>21</td>
</tr>
<tr>
<td>II</td>
<td>WEIGHT STANDARDS OF THE BRONZE AGE EASTERN MEDITERRANEAN</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>The <em>Peyem (Pym)</em> Standard</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>The Mesopotamian Standard</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>The Stater Standard</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>The <em>Qedet (Qdt)</em> Standard</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>The Ugaritic Standard</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>The <em>Necef (Ngf)</em> Standard</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>The Hittite or Asia Minor Standard</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>The <em>Beqa</em> Standard</td>
<td>36</td>
</tr>
</tbody>
</table>
### CHAPTER

<table>
<thead>
<tr>
<th>The <em>Sela</em> (Phoenician) Standard</th>
<th>37</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Aegean Standard</td>
<td>37</td>
</tr>
<tr>
<td>The History of Near Eastern Metrology: Two Case Studies</td>
<td>39</td>
</tr>
<tr>
<td>The Mesopotamian Mina</td>
<td>40</td>
</tr>
<tr>
<td>The Egyptian <em>Qedet</em></td>
<td>46</td>
</tr>
</tbody>
</table>

#### III

**THE ULUBURUN BALANCE WEIGHTS** ........................................ 49

- Preliminary Remarks .................................................. 49
- The Weight Assemblage .............................................. 57
- Distribution of the Weights on the Site .......................... 72
- Metrological Analysis ................................................ 83
- Quantal Search ....................................................... 94
- The Basic Weight Groups ........................................... 101
  - The Sphendonoid Weights ....................................... 103
  - The Domed Weights ............................................... 116
  - The Aegean Standard ............................................. 127
  - The Zoomorphic Weights ....................................... 138
- Summary and Conclusions ............................................ 149

#### IV

**THE CAPE GELIDONYA BALANCE WEIGHTS** ............................... 154

- Preliminary Remarks ................................................ 154
- The Weight Assemblage .............................................. 159
- Distribution of the Weights on the Site .......................... 170
- Metrological Analysis ................................................ 173
- Quantal Search ....................................................... 184
- The Basic Weight Groups ........................................... 192
  - The Sphendonoid Weights ....................................... 194
  - The Domed Weights ............................................... 216
- Discussion ............................................................ 255

#### V

**CONCLUSIONS** ........................................................ 278

**REFERENCES** .......................................................... 286
Volume II

APPENDIX A  KENDALL’S FORMULA ................................................. 307
APPENDIX B  CALCULATING THE ORIGINAL MASS OF A DAMAGED
WEIGHT PIECES ................................................................. 318
APPENDIX C  CATALOG OF WEIGHTS FROM ULUBURUN ............... 323
APPENDIX D  CATALOG OF WEIGHTS FROM CAPE GELIDONYA .... 502
VITA ............................................................. 581
## LIST OF TABLES

### Volume I

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Equivalences between the Ugarit, Kargamish, and Hittite Shekels</td>
<td>34</td>
</tr>
<tr>
<td>Table 2</td>
<td>Petrie's eight mass standards, the Ugaritic shekel, and the Aegean standard as established by Petruso</td>
<td>39</td>
</tr>
<tr>
<td>Table 3</td>
<td>The Uluburun balance weights</td>
<td>59</td>
</tr>
<tr>
<td>Table 4</td>
<td>The Uluburun zoomorphic weights</td>
<td>65</td>
</tr>
<tr>
<td>Table 5</td>
<td>The Uluburun lead weights, as listed in table 3</td>
<td>66</td>
</tr>
<tr>
<td>Table 6</td>
<td>The Uluburun weights and their predicted unit attributions and resultant unit masses</td>
<td>87</td>
</tr>
<tr>
<td>Table 7</td>
<td>Peak values corresponding to the quanta most likely to be represented among the 85 intact weight pieces from Uluburun</td>
<td>97</td>
</tr>
<tr>
<td>Table 8</td>
<td>Peak values corresponding to the quanta most likely to be represented among intact weights, weights with lead plugs (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]), and weights with restored masses (W 42 [KW 731], W 63 [KW 4944], W 102 [KW 3315]) from Uluburun</td>
<td>100</td>
</tr>
<tr>
<td>Table 9</td>
<td>The Uluburun sphendonoid weights with their likely unit attributions based on a unit mass of ca. 9.3 g and resultant unit masses</td>
<td>106</td>
</tr>
<tr>
<td>Table 10</td>
<td>Uluburun weight pieces of the sphendonoid group that appear to conform to a system with a standard unit mass of ca. 7.4 g, and their likely unit attributions and resultant unit masses</td>
<td>111</td>
</tr>
<tr>
<td>Table 11</td>
<td>Uluburun weight pieces of the sphendonoid group that appear to conform to a system with a standard unit mass of ca. 8.3 g, and their likely unit attributions and resultant unit masses</td>
<td>114</td>
</tr>
</tbody>
</table>
Table 12  Uluburun weight pieces of the sphendonoid group that may conform to a system with a standard unit mass of ca. 10.5 g, and their likely unit attributions and resultant unit masses  

115

Table 13  The Uluburun domed weights with their predicted unit attributions and resultant unit masses, based on a unit mass of 9.3 g  

118

Table 14  Theoretical masses for fractional and multiple units based on a standard unit mass of 9.3 g, and the probable number of examples among the Uluburun domed weights  

124

Table 15  The proposed Uluburun domed weight sets  

126

Table 16  The lead-disk weights from Uluburun  

128

Table 17  Possible unit attributions and resultant unit masses for the three pierced lead disks from Uluburun  

130

Table 18  Aegean disk weights in the mass range of 19.4 g to 20.35 g, as listed by Petruso  

132

Table 19  Double-mina fractional denominations with antithetical triangles, as listed by Petruso  

133

Table 20  Calculated multiples of the Ayia Irini double mina  

134

Table 21  Possible attributions of lead weights from Uluburun to the Aegean standard and their resulting unit masses  

134

Table 22  The Uluburun zoomorphic and anthropomorphic weights with possible unit attributions and resultant unit masses  

139

Table 23  The Cape Gelidonya balance weights  

160

Table 24  Cape Gelidonya weights with their predicted unit attributions and resultant unit masses based on a presumed standard unit mass of ca. 9.3 g  

177

Table 25  Peak values corresponding to the most likely quanta represented among the 51 intact weights from Cape Gelidonya  

185
| Table 26 | Peak values corresponding to the most likely quanta represented among the 51 intact and 6 restored (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 56n [W 54]) Cape Gelidonya weights | 189 |
| Table 27 | Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) balance weights from Cape Gelidonya, with W 64n (W 60) excluded from each population | 191 |
| Table 28 | The sphendonoid weights from Cape Gelidonya with their unit attributions based on a unit mass of 9.3 g and their resultant unit masses | 194 |
| Table 29 | Peak values corresponding to the most likely quanta represented among the 19 intact sphendonoids from Cape Gelidonya | 197 |
| Table 30 | Peak values corresponding to the most likely quanta represented among the 18 intact sphendonoids (i.e., except W 64n [W 60]), from Cape Gelidonya | 200 |
| Table 31 | Peak values corresponding to the most likely quanta represented by the 19 intact and 4 restored sphendonoids (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]) from Cape Gelidonya | 202 |
| Table 32 | Peak values corresponding to the most likely quanta represented among the 18 intact (i.e., except W 64n [W 60]) and 4 restored sphendonoids (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]) from Cape Gelidonya | 203 |
| Table 33 | The typical sphendonoids from Cape Gelidonya with their likely unit attributions and resultant unit masses | 204 |
| Table 34 | The cylindrical and loaf-shaped weights from Cape Gelidonya with their likely unit attributions and resultant unit masses | 205 |
| Table 35 | Peak values corresponding to the most likely quanta represented among only the intact typical sphendonoids, except for W 64n [W 60] (left), and the intact cylindrical and loaf-shaped groups (right), from Cape Gelidonya | 207 |
Table 36  Peak values corresponding to the most likely quanta represented among the typical sphendonoids, including the restored masses of W 23n (W 22) and W 39n (W 33), but excluding W 64n (W 60) (left), and by all cylindrical and loaf-shaped weights, including the restored masses of W 24n (W 21) and W 33n (W 30) (right), from Cape Gelidonya .............................. 209

Table 37  Decimally configured sets for generating all integer mass units between 1 and 50 ............................................. 210

Table 38  Decimally configured sets comprising 7-unit pieces in place of 10-unit pieces for generating all integer mass units between 1 and 50 .... 87

Table 39  Three sets of weights proposed for the Cape Gelidonya sphendonoids based on morphological considerations .............. 212

Table 40  Domed weights from Cape Gelidonya with their likely unit attributions and resultant unit masses ............................. 217

Table 41  Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) domed weights (including restored masses of W 32n [W 29] and W 56n [W 54]) from Cape Gelidonya. W 65n [W 66] has been excluded from both populations .................................. 221

Table 42  Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) domed weights (including restored masses of W 32n [W 29] and W 56n [W 54]) from Cape Gelidonya. W 65n [W 66] has been included in both populations . 222

Table 43  Proposed domed weight sets from Cape Gelidonya .................. 227

Table 44  The truncated-sphere domed weights from Cape Gelidonya with unit attributions based on theoretical standard unit masses of 9.3 g and 12.3 g ................................................................. 233

Table 45  The nine Cape Gelidonya weights cataloged by Bass as dome shaped, with unit attributions suggested by Petruso ................. 235

Table 46  Peak values corresponding to the most likely quanta represented
among the nine Cape Gelidonya weights cataloged by Bass as
dome shaped and used in Petruso’s analysis, with published
masses (left) and actual masses (right) ............................. 236

Table 47  Peak values corresponding to the most likely quanta represented
among the thirteen domed Cape Gelidonya weights proposed to
be elements of the truncated sphere set ............................ 238

Table 48  Unit attributions of the Cape Gelidonya typical- and flattened-
truncated sphere weights based on a standard unit mass of 11.7 g  . 239

Table 49  Peak values corresponding to the most likely quanta among only
the intact non-truncated (left), and all non-truncated (right)
weight pieces from Cape Gelidonya ............................... 241

Table 50  Attributions and resultant unit masses of truncated cones from
Gelidonya based on a standard unit mass of 9.3 g .................. 244

Table 51  Results of quantal search among the truncated cone weights
from Cape Gelidonya ..................................................... 245

Table 52  Possible unit attributions of Cape Gelidonya weights W 11n
(W 11), W 12n (W 12), W 16n (W 15), W 22n (W 20), W 29n
(W 26), W 31n (W 28), W 34n (W 31), W 41n (W 41), and
W 50n (W 47), based on standard unit masses of 7.3 g, 9.1 g,
and 8.6 g .................................................................. 246

Table 53  Cape Gelidonya lentoid weights with their proposed unit
attributions and resultant unit masses ............................... 250

Table 54  Peak values corresponding to the most likely quanta among the
intact lentoids (left) and for all lentoids (right) from Cape
Gelidonya ................................................................. 251

Table 55  Unit attributions of Cape Gelidonya lentoid weights with respect
to the three possible standard unit masses suggested by
Kendall’s statistic ......................................................... 252

Table 56  Differences between published and recently measured masses of
the Cape Gelidonya weights ........................................... 258
Table 57  Peak values corresponding to the most likely quanta represented among the 45 well-preserved weights from Ayia Irini, Keos ..... 262

Table 58  Unit attributions of the sphendonoid weights based on standard unit masses of 9.4 g and 65 g .......................... 271

Volume II

Table 59  Quantally configured hypothetical sets based on standard unit masses of 9.3 g, 8.4 g, and 12.3 g .......................... 310

Table 60  Peak values corresponding to the most likely quanta represented among the quantally configured hypothetical sets based on standard unit masses of 9.3 g, 8.4 g, and 12.3 g .......................... 312

Table 61  Peak values corresponding to the most likely quanta represented among the quantally configured hypothetical sets based on combined standard unit masses of 9.3 g and 8.4 g (left), and 9.3 g, 8.4 g, and 12.3 g (right) ........................................ 316
### LIST OF FIGURES

**Volume I**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Site plan of the Uluburun shipwreck</td>
<td>73</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Distribution of sphendonoid weights at Uluburun</td>
<td>76</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Distribution of domed and lead weights at Uluburun</td>
<td>77</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Distribution of zoomorphic weights at Uluburun</td>
<td>78</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Plotted results of Kendall’s statistic for the 85 intact weight pieces from Uluburun</td>
<td>96</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Plotted results of Kendall’s statistic for intact weights, weights with lead plugs (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]), and damaged weights with their restored masses (W 42 [KW 731], W 63 [KW 4944], W 102 [KW 3315]) from Uluburun</td>
<td>99</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Proposed fraction and multiple attributions of the standard unit mass of 9.3 g evident in the Uluburun sphendonoid weights in the range of 0 g to 15 g</td>
<td>109</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Proposed multiple attributions of the standard unit mass of 9.3 g evident in the Uluburun sphendonoid weights in the range of 15 g to 100 g</td>
<td>110</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Proposed fractions and multiple attributions of the standard unit mass of ca. 9.3 g evident in the Uluburun domed weights in the range of 0 g to 30 g.</td>
<td>120</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Proposed multiple attributions of the standard unit mass of ca. 9.3 g evident in the Uluburun domed weights in the range of 30 g to 500 g. Two 100-unit weights of 916.7 g (W 127 [KW 477]) and 925.6 g (cal.) (W 128 [KW 1511]), and damaged weights W 1109 (KW 3840) and W 123 (KW 3099) are not shown.</td>
<td>121</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Site plan (after Bass 1967) of the Cape Gelidonya shipwreck with</td>
<td></td>
</tr>
</tbody>
</table>
locations of weights and their types indicated .................................................. 157

Figure 12 Proposed fractional and multiple attributions of the standard unit mass of ca. 9.3 g evident in the Cape Gelidonya balance weights in the range of 0 g to 80 g ........................................................ 182

Figure 13 Proposed multiple attributions of the standard unit mass of ca. 9.3 g evident in the Cape Gelidonya balance weights in the range of 80 g to 500 g ................................................................. 183

Figure 14 Plotted results of Kendall's statistic for the 51 intact weights from Cape Gelidonya (i.e., except W 5n [W6], W 20n [W16], W 21n [W19], W 24n [W21], W 23n [W22], W32n [W29], W 33n [W30], W 39n [W33], W 56n [W54]) ........................................ 186

Figure 15 Plotted results of Kendall's statistic for the 51 intact and 6 restored weights (W 24n [W21], W 23n [W22], W 32n [W29], W 33n [W30], W 39n [W33], W 54n [W51]) from Cape Gelidonya .......... 190

Figure 16 Plotted results of Kendall's statistic for the 19 intact sphendonoids from Cape Gelidonya ................................................................. 198

Figure 17 Plotted results of Kendall's statistic for the 19 intact sphendonoids and 4 restored sphendonoids (W 24n [W21], W 23n [W22], W 33n [W30], 39n [W33]) from Cape Gelidonya ........................................ 201

Figure 18 Plotted results of Kendall's statistic for the intact typical sphendonoids from Cape Gelidonya ................................................................. 206

Figure 19 Plotted results of Kendall's statistic for all typical sphendonoids from Cape Gelidonya, including restored masses of W 23n (W22) and W 39n (W33) .................................................. 208

Figure 20 Plotted results of Kendall's statistic for intact domed weights from Cape Gelidonya (i.e., excluding damaged pieces W 5n [W6], W 20n [W16], W 21n [W19], W 32n [W29], W 56n [W54], and underweight W 65n [W66]) ......................... 220

Figure 21 Plotted results of Kendall's statistic for the 45 well-preserved weights from Ayia Irini, Keos ................................................................. 261
Volume II

Figure 22  Plotted results of Kendall's statistic for a quantally configured hypothetical set based on a standard unit mass of 9.3 g ........... 311

Figure 23  Plotted results of Kendall's statistic for a quantally configured hypothetical set based on a standard unit mass of 8.4 g ........... 311

Figure 24  Plotted results of Kendall's statistic for a quantally configured hypothetical set based on a standard unit mass of 12.3 g ........... 312

Figure 25  Plotted results of Kendall's statistic for a quantally configured hypothetical set based on combined standard unit masses of 9.3 g and 8.4 g ................................................. 315

Figure 25  Plotted results of Kendall's statistic for a quantally configured hypothetical set based on combined standard unit masses of 9.3 g, 8.4 g, and 12.3 g ................................................. 316
CHAPTER I
INTRODUCTION: METHODOLOGICAL PROBLEMS, PRINCIPLES, AND PROCEDURES

Every ancient seafaring merchant probably carried his own set or sets of pan-balance weights, which would have been needed for the conducting of commercial transactions in port. Weights were used not only for commercial transactions, but were equally important in metal-working establishments. They are shown in Egyptian wall-painting scenes depicting smiths at work (Davies 1973: 52, pl. LV; Newberry 1893: 31, pl. 11; Pritchard 1969: 37, fig. 122, 40, fig. 133, 264-65), including one that depicts copper and tin ingots being melted down and recast. Not only did the prices of finished objects depend at least in part on their weight, as they do today, but the proportions of metals to be alloyed must have been specified in advance. The importance of weighing metal objects carefully is indicated in Hittite and Ugaritic texts, the latter perhaps mentioning the weighing of ingots (Montgomery 1934: 60).

The following study represents years of intermittent investigation of balance weights and related equipment that were carried by seafaring merchants in general, and by merchants on Bronze Age Mediterranean ships in particular. Its methodology is rooted in the works of many earlier students of metrology, and benefits immensely from their discoveries and insights, while trying to avoid the pitfalls they suffered. Materially, it is based upon an analysis of over 200 balance weight specimens from two diachronic shipwrecks of the Late Bronze Age excavated off the southern coast of Turkey: the late-fourteenth century B.C.E. site at Uluburun and the late-thirteenth or early-twelth century B.C.E. site at Cape Gelidonya. They are the largest and most complete sets of balance weights recovered from Late Bronze Age archaeological

This dissertation follows the Bulletin of the American Schools of Oriental Research in style and format.
sites.

These two balance weight assemblages provide a rare glimpse into the world of Bronze Age merchants and their tools of profession. With individual balance weights, complete weight sets, and pan balances that were in concurrent use, we have an extraordinary opportunity to discover the mathematical substratum on which their system of mass was based, as well as its standard unit of mass and denominational configuration. Moreover, by comparing the two diachronic assemblages, separated in time by about a century, we may be able to judge whether the mass standards were subject to change over time.

Yet the study of ancient weight systems and their mass standards used in the eastern Mediterranean regions poses problems that are specific and sometimes unique to each area within this large region, and often unlike those encountered elsewhere with other metrological standards. Therefore, before delving into the artifactual evidence recovered from the Late Bronze Age shipwrecks at Uluburun and Cape Gelidonya and its implications for weighing in the Late Bronze Age Near East, we must set out the methodological problems, principles, and procedures that have guided our analysis of that evidence.

The Identification of Near Eastern Balance Weights

What constitutes a balance weight and how does one recognize it? This is an aspect that the earlier metrologists were hardly able to address with their limited evidence. A stone or metal piece inscribed with a unit of measure, preferably with the name of some guaranteeing authority, can of course be unequivocally recognized as a weight piece representing a certain standard. One may also identify with some confidence all finely worked pieces of hematite and some other stones in the shape of sphenodonoids (ellipsoids or elongated barrels), truncated spheres, domed pieces, and ducks as ancient weight pieces. The examination of other balance weight collections, however, reveals pieces of shaped stones that obviously do not belong to any such
morphological types, but do bear markings, presumably denoting units of mass, that identify them as weight specimens. Alongside these non-typical marked specimens are other stone pieces of identical or similar shape, but without a mark of any kind to indicate its standard and/or denomination. If these had been found in isolation, or in a context that did not reveal their functions as weight pieces, one would be hard pressed to identify them as such. The metrologist is thus faced with a difficult choice. In order to minimize error, he may choose to include in his study only those marked pieces that can be unequivocally identified as weights and exclude all unmarked specimens. Such an elimination process, however, will undoubtedly result in a norm that is biased toward the sanctioned, or precision, norms. Conversely, he could choose to incorporate also the unmarked weight pieces, but then risk admitting objects to the group that never actually functioned as weights. Normally, the resolution of this problem would require a much more thorough study of diverse archaeological material and the processing of a larger body of data, but when dealing with material confined to Bronze Age shipwrecks, the variety of artifacts that may be mistaken for balance weight pieces is somewhat more limited. If equipped with a thorough knowledge and the ability to identify material related to ships and ship-borne equipment, therefore, one can, with some confidence, identify most weight pieces correctly, especially those of higher denominations. Smaller pieces of seemingly unworked or semi-worked stones are more troublesome, as they may represent pebbles or pieces of colored stone that seamen ground to shape for personal use as amulets, pendants, and beads.

Pebbles and other bits of naturally polished stone that may have been put to use as personalized weight pieces by those on board are also difficult to identify. Usually, such pieces are difficult to recognize as objects during the course of an underwater excavation, as they frequently resemble naturally occurring pebbles on the seabed, and even when they are recognized and raised as ship-related material, it is extremely difficult, if not impossible, to distinguish them from pebble ballast. As a consequence, I have preferred to err on the side of caution and follow a more conservative analytical
course by excluding pieces that cannot with certainty be classified as weights.

*Materials Used for Near Eastern Balance Weights.* A balance weight may be
crafted from any reasonably solid, heavy, and chip-resistant material to conform to a
specific quantity of mass with a certain degree of accuracy. This accuracy may be
dictated by the individual who will use the weight, by a central authority empowered
to regulate weight standards and the accuracy of weight pieces, or by the demands of
the specific task to which the weights are to be applied. As balance weights are
subject to considerable attrition from continual use, it is desirable that they be
manufactured of durable materials in relatively smooth shapes to minimize damage.
While most ancient weight specimens conform to these basic practical criteria, a
certain class of Late Bronze Age weights cast in metal, usually bronze, in the form of
intricate and delicate zoomorphic and, more rarely, anthropomorphic, shapes do not.
Such weights, whose projecting features could be easily damaged during everyday
weighing activities, thereby rendering them underweight or practically useless, must
have had some special purpose, one that probably did not require frequent mercantile
weighing of everyday commodities. That purpose is unfortunately now lost to us.

Stone was the most common material from which weight pieces were crafted
in the ancient Near East, and the corpus of prehistoric stone weights displays an
extensive array of types, but the ideal stone would have been one soft enough to shape
without much effort, yet hard enough to tolerate rough and extended use. The most
commonly employed types were hard, such as hematite (and its related iron-bearing
minerals), jasper, basalt, quartzite, and diorite. Those that were easier to work, such
as limestone and steatite, were also used, but to a lesser extent. In fact, the easiest
method by which a merchant could acquire his personal set of weights was to obtain
pebbles equal in mass to commercially made balance weights in common use. In the
case of overweight pebbles, the excess mass could have been easily eliminated by
grinding away a certain portion of the pebble until the desired mass was obtained.

By far the most common type of stone used in the ancient Near East was
hematite (Fe₂O₃), an oxide of iron, and related minerals such as magnetite, goethite, limonite, and ilmenite. The relative hardness of hematite (about 6-6.5 on the Mohs scale), and its high density (ca. 5.2-5.3 g/cm³) required greater time and effort in shaping balance weights of this material. Such weights, however, are not only extremely resistant to chipping, but are also relatively small and compact. Moreover, being an oxidized form of iron, hematite is chemically inert and does not gain or lose weight due to corrosion or deterioration, an important consideration for use at sea, where the corrosive effects of salt water would be extremely harsh on weights of metal. Hematite’s dense crystalline structure and homogeneous fabric (relatively non-porous) render it virtually impermeable to water or humidity, which in balance weights made of porous materials can cause considerable fluctuations in mass. It takes a high polish, which not only gives hematite weights an attractive appearance, but also readily reveals chips and other surface damage that compromise the validity of a weight piece. All of these factors are important in ensuring consistency in weighing practices.

Hematite, was also relatively easy to obtain, as it has a widespread natural occurrence.

After hematite, bronze is the most frequently used balance weight material. While susceptible to some corrosion during normal use and not as hard as stone, it offers the advantage of quick and facile replication of large numbers of weights by casting. Like hematite, its mass is not altered appreciably by humidity or exposure to a wet environment, but it is denser (ca. 8.35 - 8.65 g/cm³) (Laing and Rolfe 1941: 34) and less brittle, and the manufacture of bronze balance weights necessitates a knowledge of and experience in metallurgy and pyrotechnology. Many ancient Near Eastern bronze balance weights, especially those in zoomorphic shapes, incorporated lead as a core material for weights having a bronze shell (the use of bi-metallic weights may have been of Syrian inspiration [Petruso 1992: 2]). Lead plugs were also used, ostensibly for easy adjustment of the mass as necessary, as they were with hematite balance weights.

Another material used for balance weights was lead. Lead oxidizes readily on
contact with most organic acids and takes on weight, so its mass is not nearly so stable as that of stone or bronze (Petruso 1992: 2). Balance weights made only of lead are soft and easily deformed even under careful use, and such surface damage makes it more likely that lead weights will lose portions of their surfaces. For these reasons, lead was not a common material of choice for balance weights in the ancient Near East. Yet one is confronted with a contradictory situation in the Bronze Age Aegean, where lead was the predominant material used. Balance weights, in fact, make up by far the single largest group in the Aegean corpus of lead objects (Buchholz 1973: 281; Petruso 1992: 2). The popularity of lead for balance weights in the Bronze Age Aegean undoubtedly was due to the relative ease with which it could be worked into a weight piece of desired mass. Unlike bronze, its lower melting temperature facilitated casting without sophisticated metallurgical knowledge. Moreover, the excess mass could be easily eliminated by shaving or filing the appropriate amount of lead from the cast piece. While Petruso (1992: 2) attributes the popularity of lead weights in the Aegean world to availability and convenience of manufacture, which kept their cost down and made them more generally available, this does not explain why lead was not also adopted as the primary raw material for balance weights elsewhere in the eastern Mediterranean. Surely, lead was readily available there as well, for it was commonly employed not only for casting votive figurines and making sinkers for fish lines and nets, but also to fill cores of hollow-cast balance weights of bronze, mostly in zoomorphic shapes.

Some have suggested that clay was also a material used to manufacture balance weights. A number of small terra-cotta balls found at Enkomi on Cyprus, some of which carry inscriptions in Cypro-Minoan syllabary, have been interpreted as balance weights (Persson 1932). Petruso (1992: 2) notes, however, that clay is one of the least desirable materials from which balance weight might have been made, as it is extremely difficult to predict the mass of a lump of fired clay based on its mass when wet or plastic, and also its low density would require that a clay weight be far larger
than one made of a denser material. To have the mass of a cube-shaped weight of hematite weighing 6 g, a clay cube would have to be four times as large! Furthermore, because terra cotta is hygroscopic, i.e., affected by ambient humidity, a clay balance weight piece will gain weight by absorption when conditions are humid and lose weight when conditions are dry. Clay is also more susceptible to chipping or breakage than stone or metal. Persson (1932: 272) suggested that the terra-cotta balls from Enkomi were placed on balance pans along with standard weight pieces during weighing of a certain commodity, with the extra amount of the commodity that had to be placed on the balance to counteract the mass of the clay ball(s) being royal tribute for the palace. Petruso (1992: 2) rightly asks why, at a place like Enkomi, where many dozens of finely made weights of hematite and other stone have been found, taxation should have been assessed with “such haphazardly made and distinctly un-royal equipment as small terra-cotta balls.” Moreover, Petruso (1992: 2, n. 3) reports that the 14 terra-cotta balls from Enkomi in the British Museum and the Louvre have masses that range from 3.9 g to 23.3 g with no significant clustering, which makes it quite unlikely that they served as balance weights. Although not an exactly parallel situation, it is noteworthy that in recent times, pottery sherds reworked into rough disks were used as weight pieces among the Akan of the African Gold Coast (Garrard 1980: 29-30, 32, 42, 181 fig. 25). The exact circumstances under which these weights were used, instead of those traditionally of bronze, is not known, but as some were excavated near gold mines, it is likely that they represent personal weights of miners or local merchants. Petrie (1926: 17) reports the use in Oriental markets of unusual masses as weights including scraps of China plates, and Kisch (1966: 86, fig. 38, 89) records weights of glazed terra cotta made in Switzerland up to the nineteenth century.

Shapes of Near Eastern Balance Weights. The most recognizable shapes of Near Eastern balance weights are the so-called “sphendonoid” and the “domed” (domed-top, or cupcake-shaped) shapes. But balance weights of other geometric,
irregular, and zoomorphic shapes do occur. Each of these shapes will be discussed separately.

The term sphendonoid was coined by Evans (1906: 348) from the Greek word σφηνόδον (sling or sling bullet) to describe some of his weight pieces that were shaped like the oblong sling bullets of lead, stone, or clay used in antiquity. This type of balance weight has been variously termed fusiform, fusiole, olive pit, sling bullet, barrel, cigar, and spindle. Its oblong shape is usually pointed at both ends and flattened on one side, which served as its base. This shape was quite popular in the Bronze Age Levant, Egypt, and Cyprus, and is represented in the Aegean region by many examples from Troy and, more rarely, mainland Greece, where the dominant weight shape was the lead disk. Petrie (1926: 6) believed the sphendonoid shape to be Syrian in origin, but noted that the earliest known example was from First Dynasty Egypt (Tomb of Zer). It became most popular in Egypt, however, during the Eighteenth Dynasty (Hemmy 1937: 42), the era of Egypt's greatest intercourse with Syria. While hematite was the material of choice for this shape, many examples in other materials exist. On the Uluburun shipwreck, nearly three-quarters of the balance weights in the "typical" sphendonoid shape are of hematite, four are of diorite, two are of limestone, one is of steatite, and the remainder are of bronze. The proportion of bronze weights to that of stone are provocative, as they are clearly at odds with the relative scarcity of bronze sphendonoid weights discovered from terrestrial sites. This may be explained in part by the fact that, as bronze was a prized and expensive material, many bronze objects, including damaged or otherwise unusable weight pieces, probably found their way quickly to the crucible to be made into other objects. In this light, even though bronze weights are poorly represented in archaeological assemblages, the dearth of specimens recovered need not necessarily reflect the actual quantities of bronze weight pieces used in antiquity.

Petrie constructed a typology for the varieties of the basic sphendonoid weights (1926: pl. VI-VIII), but there appear to be no satisfactory correlations
between the variants of the shapes and chronology. It seems more likely that some of the morphological nuances were due simply to matters of preference.

The weight shape most frequently encountered after the sphendonoid is the domed shape, also referred to, in its various forms, as the cup-cake, dome-top, truncated sphere, and flattened sphere. It almost certainly originated in Egypt and is synonymous with the characteristic decimal system of weight mensuration used by the Egyptians. For the purpose of our study, this shape type encompasses all weight pieces with a circular top view, or projection. Weight specimens with any elongated or oblong features should, therefore, be assigned to the sphendonoids or some other group, as has been done in succeeding chapters. There are many variants of the shape and, as with the sphendonoids, Petrie (1926: 4-7) proposed a typology based on chronological seriation. While such dating may be valid for some of the weight shapes, it should be remembered that many of the weight pieces used in Petrie’s study were purchased from dealers and, therefore, lack proper archaeological contexts. The unreliability of his chronological seriation by shape alone is also amply demonstrated by the variety of domed shapes found on the Uluburun shipwreck that do not comply with Petrie’s groupings.

Another shape group observed among eastern Mediterranean balance weights comprises those crafted in zoomorphic and, more rarely, anthropomorphic forms, usually bronze. Zoomorphic shapes were quite popular in Egypt, with at least 60 examples reported (Cour-Marty 1990: 27, 42, fig. 14), the Levant, and on Cyprus. On the other hand, only two zoomorphic balance weights have been reported from the Aegean: an ox head and a calf head (Petruso 1978b: 180, 203, 252, fig. 56). Both of these forms were very popular on Cyprus and in Syria during the second millennium, and are surely of Near Eastern inspiration, if not origin. The three small carnelian ducks from eastern Crete cataloged as balance weight by Evans (1906: 351-52, nos. 29-31) are more likely beads or amulets, as all are quite light (under 2.6 g) and pierced for suspension (Petruso 1992: 3-4; Sakellarakis 1971: 225).
**Principles of Identifying Weights.** While the great majority of ancient artifacts inventoried and published as balance weights are recognizable as such, some confusion in identification has occurred. In evaluating an unmarked stone object of simple shape, Petruso (1992: 4) recommends the following before identifying it as a weight. Seek first to find a possible use for the object as a ground stone implement. If one surface is finely polished (as in stones for grinding grain), pecked (as in stone pounders or pestles), or depressed (as in pivots for tinder drills), for example, the object probably is not a weight. This in fact proved to be the case for a stone object from Uluburun (KW 753) cataloged in the field as a weight specimen. When examined closely it was found to be a rubbing stone for one of the grinding trays found on the site. This, however, does not preclude the possibility that the piece might have had a secondary or concurrent use as a weight, as it is not uncommon to observe in the Mediterranean today weight pieces being used as nutcrackers, hammers, pestles, and the like, for which purposes, it must be admitted, many are aptly suited.

The design of ancient balances, which were of the simple pan-type with mostly flat pans of sheet copper or bronze, precluded the need for balance weights to be pierced or otherwise modified (except for suspension in the case of very high masses), as there was no advantage to such. Petruso (1992: 4), therefore, dismisses or only provisionally accepts pierced objects as balance weights and considers such items more likely to be loom weights, or sinkers for fish nets or lines. Because they would readily roll off the balance pans, he also rejects spherical objects and non-flattened sphendonoids as balance weights. The latter are more likely to have been sling bullets, especially if made of lead, stone, or clay.

**Ancient Weight Systems and Practical Factors, or Bases.** Ancient weight systems are built on multiples and fractions that are practical ways of expressing the abstract concept called numbers. Numbers, on the other hand, are denoted according to a certain factor, or base, which defines a specific system. A number system factored or based on the integer number 10, for example, is said to be a decimal system,
whereby the elements of the system are evenly divisible by 10. The most common bases used in ancient metrical systems were apparently the binary (2-factor), the decimal (10-factor), the duodecimal (12-factor), and the sexagesimal (60-factor).

Because a balance of the double-pan type has a pan attached to each end of the balance beam or arm, binary processes would appear to come naturally to a person, as they are the easiest functions to carry out on such a simple weighing device. Consequently, the main attraction for using a binary system of mass mensuration is that it greatly facilitates the generation of higher (or lower) increments of the standard unit. Each successively heavier denomination would be achieved simply by doubling a weight piece's original mass. The resultant denomination could then be tested easily for accuracy by simply placing it in one pan, and in the opposite pan, the two identical weight pieces from which it was generated.

To demonstrate the generative process of the binary factor, let us consider the weight system used in the Indus Valley civilization during the third millennium B.C.E. Hemmy (1931, 1938) determined, through mathematical analysis of the corpus of balance weights from Mohenjo-daro and Harappa, the two main urban centers of the Indus Valley, that the system had a simple binary substratum (base). The system's standard unit mass (of 0.857 g) was found in multiples of 1, 2 (2^1), 4 (2^2), 8 (2^3), 16 (2^4), 32 (2^5), and 64 (2^6) (Hemmy, 1938: 606), but also in larger multiples of 160 (2^4x10), 200 (2^4x100), 320 (2^5x10), 640 (2^5x100), 1600 (2^4x100), 3200 (2^5x100), 8000 (2^5x1000), and 128,000 (2^7x1000) (Petruso 1992: 10). The presence of 10, 100 (10^2), and 1,000 (10^3) in the larger multiples indicates that the decimal base was also known and used for larger values (Petruso 1981a: 47-48; 1992:10). According to Petruso (1992:10) although both the binary and decimal systems were used simultaneously in the Indus Valley, the latter system chronologically followed the advent of the simple binary system. Binary generation by doubling and halving was also used in Mesopotamian and Egyptian mathematics (Petruso 1992: 10).

The ancient application of the decimal base was most widespread in Egypt,
where it was in use at least as early as the third millennium (Vercoutter 1963: 18). In
the New Kingdom the smallest decimal unit of mass was the qedet, with ten qedets to
one deben, and ten debens to a sep. Although the origins of the decimal system used
specifically for mass mensuration in Egypt are obscure, Petruso (1992: 10) suggests
that the earliest group of weights found there (Petrie 1926: 4), dating to the Early
Predynastic (Amratian) period of the early fourth millennium (Skinner 1967: pl. 1),
may plausibly be regarded as decimal in mode. He notes further, however, that the
seemingly decimal nature of the Amratian weights does not necessarily imply that the
decimal base was fully absorbed and used in both its practical and mathematical
capacities. Even though the concept of one hundred was known in Egypt by the early
historical period, evidence suggests that it was grasped only with time and some
difficulty, though once comprehended, analogous concepts of the higher powers of 10
appear to have followed fairly quickly. Therefore, it is not known whether “the
makers and owners of the Amratian weights knew or envisioned the practical, let alone
computational, usefulness that would accrue to knowing the relationship between ten
and its powers” (Petruso 1992: 10).

A duodecimal base (12), is a somewhat more practical and manipulable system
than the decimal, as it is still manageably small yet yields whole-number, or integer,
quotients when divided by four smaller divisors (2, 3, 4, and 6) (Petruso 1992: 11). In
the decimal system, on the other hand, the standard unit is divisible by only half as
many divisors (2 and 5).

A sexagesimal base (60) is aptly summed up by Petruso (1992: 11) as
“combining the ease of performing fractional operations possessed by the binary and
duodecimal bases, with a certain amount of the computational flexibility inherent in the
decimal base.” This system found widespread popularity among the Sumerians by the
third millennium, and later among the Babylonians (cf. Powell 1971).

Petruso (1992: 11) cautions against the temptation to attribute to an ancient
society only one mathematical substratum. In Babylonia, for example, a sexagesimal
system consistently was used only in the pure sciences (i.e., astronomy and mathematics), while applied sciences (i.e., measurements of time, mass, and area) used a combination of systems (Neugebauer 1952: 17). It is impossible to know exactly why each society prefers the specific standard it uses. But then, this seems only natural and is to be expected, as such is the case even in our own time. Usually those systems that best suit a society’s goals are chosen, for while each may have its own merits that recommend it, additional subjective factors influence the final decision.

**Factors Affecting the Determination of Mass Standards**

For the early metrologists, the most profound analytical problem was the definition and isolation of a norm, or mass standard, for it is not uncommon that two perfectly preserved weight specimens bear the same denominational marks, but have different mass values. How is one to approach and interpret such a situation? Further, what denomination should one assign to any particular weight specimen? In the analysis of unmarked weight specimens, their attribution to specific denominations is a major problem. Usually this is not so complicated for Near Eastern weights with higher units of mass, as the only units utilized above 10 shekels, with rare exception, were 20 and 30 shekels, and less frequently, 15 and 40 shekels, followed by multiples or fractions of the mina (50 shekels), all of which may be easily distinguished by weighing. After having studied more than 950 Near Eastern weight specimens, Powell (1979: 73, n. 6) notes that aside from Assyrian weights, where the mina is divided into 2, 3, 4, 5, 6, and 8 parts, he has observed only a single denomination other than 10, 15, 20, 30, and 40 shekels: an 11-shekel weight from Khafjah (Tulub). Of the denominations higher than 10 units in the Uluburun assemblage, there are no 15- or 40-unit pieces, but weight pieces of 10, 20, 30, 50 (1 mina), and 100 units (2 minas) are present. As for the attribution of weight pieces with a mass less than 10 units, this is often more problematic, and those below one unit are frequently difficult to distinguish from one another, especially if they represent different mass standards.
Of the weight specimens ranging in mass from slightly under 3 g to slightly over 7 g stored in the Oriental Institute (mostly from Ischali), Powell (1979: 73) was able to utilize only about one-sixth of the total of 150 balance weights because of the difficulty of determining their denominations. Such uncertainty arose from the occurrence of marked balance weights representing denominations smaller than one unit that reflect mass norms in excess of the acceptable range of the norm, as represented by denominations equal to or greater than one unit (Powell 1979: 73, n. 8). This seems to indicate that ancient weight makers experienced more difficulty in achieving accuracy of mass in the smaller denominations and especially fractional units, than in the larger denominations. In fact, this tendency toward greater inaccuracy in smaller units of mass appears to confirmed by the evidence we have from ancient balances themselves (see The Balances).

Powell (1979: 73-74) relates that for structural as well as practical reasons, one would expect a set of Mesopotamian shekel-fraction weights to contain one or more specimens of each of the following denominations: 1, 2, 3, 5, 10, 15, 30, and 60 barley corns (60 barley corns = 1 shekel). He further notes that evidence from ancient lexical texts indicates an even finer gradation of shekel-fractions: 1/3, 1/2, 1, 2, 3, 4, 5, 10, 15, 20, 22.5, 30, 36, 45, 60, 90, and 120 barley corns. If one were to assign mass values to each of these fractions based on a mina (= 50 shekels) norm of 504 ± 16 g, a significant number of perfectly preserved precision weights would still fall outside the mass values deemed acceptable for these pieces. Thus, the problem of successfully attributing fractional shekels remains to be solved.

Let us now look at the major factors that affect our ability to discover with accuracy the absolute mass of an ancient standard and its denominations. We are hindered by various potential sources of error, and those that bear most directly on such efforts, as listed by Petruso (1992: 6-7) and Cherry (1983: 52-56), are given with supplementation below.

Current Condition of the Weight Specimens. The degree of preservation of
weight specimens can produce inaccurate mass measurements in two ways. First, balance weights can suffer some loss of mass through general attrition of their surfaces during use, and even physical damage in the form of chipping. Second, mass loss or gain can occur after the deposition of the balance weight into the archaeological record. Many weights, especially those of stone, can gain mass through the deposition of salts and other encrustation-forming materials on their surfaces, or suffer mass loss through dissolution and leaching, in the case of submerged specimens. Balance weights made of metal lose material through exfoliation of corroded surface layers. All of these effects are usually more pronounced on weight pieces recovered from underwater sites. In some instances the pieces are so extensively encrusted that it is difficult to recognize them as weights. Conversely, some metal weights, especially those of bronze, lose so much of their original metallic constitution that, while the overall shape appears to be unaltered, the weight piece is in fact but a shell of the original, with a preserved mass only a very small fraction of its original.

The weight pieces recovered from the shipwrecks at Uluburun and Cape Gelidonya have been thoroughly cleaned of all visible surface deposits and desalinated in distilled water until virtually no absorbed sea salts now remain. This ensures that the mass of each weight piece from both assemblages, except for those damaged during or subsequent to the ship's demise, represents the original value or, possibly, a somewhat lighter version. The latter is a consequence of either nearly imperceptible physical damage in the form or microchips, and/or possible dissolution of inclusions in the original matrix of the stone due to prolonged submersion. The dissolution of material may be responsible for the pitting frequently observed on the surfaces of most hematite weights from both shipwreck sites, because it is certainly likely that many were originally polished as well as those found on land excavations. Regardless of how a weight's original mass has been altered, the point to remember is that, due to thorough cleaning and desalination of each piece, with one exception, no stone weight presented here is heavier than it was when the ship that was carrying it sank.
Therefore, the standard unit mass obtained from these weight pieces will be either the value inherent in their manufacture, or one that is somewhat lighter, but never one that is heavier.

**The Balances.** The materials from which ancient balances were made, their design, their size, and the amount of care taken in their manufacture, use, and maintenance determined their sensitivity (the smallest amount of additional mass necessary to produce a discernable movement in the beam), and thus the accuracy of mass mensuration. Hemmy (1937: 40) notes that a Greco-Egyptian goldsmith’s balance of ca. 600 B.C.E. has a sensitivity of 3%, and that the lengths of the beam’s arms differ by about 3%. Such a balance could conceivably result in a cumulative error of about 6%. An Egyptian balance from the Eighteenth Dynasty is somewhat better: a sensitivity of 2%, and a difference in the lengths of the arms of 1/2%. Skinner discusses the technological innovations in ancient balances leading to greater sensitivity. Tests with a plaster cast of a limestone beam from about 3300 B.C.E., a replica based on an Egyptian depiction from about 2400 B.C.E., and an original wooden beam from ca. 1360 B.C.E. show an increase in sensitivity from about 2% to 1% (Skinner 1967: 6-7, 33, 39, 47-49). Berriman (1955b: 50) indicates that tests made on an ancient cord-pivot balance revealed a sensitivity of 2% with 5 g in each pan, of 0.4% with 50 g, and of 0.1% with 500 g or more (also in Petruso 1992: 76).

**Inaccuracies in the Duplication of Balance Weights.** Petruso (1992: 6), citing Hemmy (1937: 40) and Skinner (1967: 28), comments that one should expect to observe considerable variation in the masses of ancient balance weights, because the majority of them were not direct copies of sanctioned pieces against which they could be checked, but copies of copies. In general, the greater the number of copy “generations” of a particular denomination, the wider the margin of error will be for the weight piece in question.

**The Degree of Accuracy Acceptable to Those Who Used the Equipment.** Early metrological standards were probably crude, but nonetheless sufficient for the needs of
the people who developed them at the time, just as our modern standards are for our own needs (Judson 1956: 2, 7). The acceptable degree of accuracy certainly varied from person to person, from region to region, from task to task, and from period to period, and determining the tolerances "acceptable" within any particular ancient standard is all the more difficult, if not impossible, because they are completely amalgamated with the three factors cited above. A further complication of this issue, echoed by Petruso (1992: 7), is that there might have been, for any given ancient metrical scale, two acceptable standard units, a smaller and larger. He notes a similar situation involving the length of the foot used by architects of Classical Olynthus in Greece. Hemmy (1931: 589, cited in Petruso 1992: 7) comments that the assumption by metrologists that any given heavy weight specimen (as opposed to light, hence less accurate, weight pieces) made with great care and in a good state of preservation may be taken as an accurate representative of its standard, and that other sub- or multiple-units of that standard can be derived from it, is not justified by the evidence, especially in the earlier periods.

Local and Geographical Variants of a Standard Unit of Mass. A certain standard unit of mass may have regional and/or geographical variations that completely supplant its original value, or it may become reserved for specialized applications such as taxation, tribute, or transactions involving specific commodities. Ancient Palestinian weights, for example, are notoriously difficult to analyze for this reason (Guy and Engberg 1938: 7).

Chronological Variations in the Mass Value of a Standard Unit of Mass. In antiquity, as in recent times, market forces as well as political circumstances could have caused, over time, fluctuations in the value of certain mass standards. It is precisely this difficulty that will be addressed by means of the balance weights from the Uluburun and Cape Gelidonya shipwrecks. As these are the largest collections of contemporaneous weights known to have been in use virtually until the moment of their entry into the archaeological record, all of the weight pieces have been evaluated
carefully with an emphasis on detecting possible fluctuations within different weight sets (when it has been possible to attribute weights to specific sets), among the elements comprising a specific set, and between the two assemblages generally. Neither assemblage should reflect, in itself, significant fluctuations that could be attributable only to the passage of time, but when viewed in a diachronic light, they may very well reveal such fluctuations.

*Errors in Measuring and Recording Mass.* Petruso (1992: 7) understandably regards poor mensuration and recording as inexcusable and the most frustrating of all the factors mentioned here. These errors result either from the use of inadequate or incompatible equipment, or from typographical mistakes in publication. To prevent such easily made and nearly unavoidable errors, each balance weight from the Uluburun and Cape Gelidonya assemblages has been weighed on the same electronic scale, an Ohaus *Precision Plus*, model TP4KD, which is accurate to ± 0.01 g from 0 to 800 g and to ± 0.1 g from 801 g to 2,000 g. Each weight piece was weighed five consecutive times, with the most frequently registered value taken as the mass for the piece. This procedure was repeated within two months of the initial weighing in the summer of 1995, and both assemblages were weighed yet a third time, in October of 1996, to detect mass fluctuations due to the wet conditions that prevail during the autumn in Bodrum, Turkey, where both collections are stored.

**Principles of Investigation**

Anyone who has dealt with ancient metrology, even in a superficial manner, is aware of the difficulty in reaching definitive conclusions regarding ancient metrological norms, even when cognizant of the existence of such norms. Faced with the problems just outlined, then, how can one arrive at a valid standard unit mass and its denominations for a group of balance weights? Again, Petruso (1992: 8) formulates the principles of investigation to which I have adhered in this study, although some are inherent in the very nature of the shipwreck weight assemblages. These principles may
be summarized as follows:

1) The corpus of weights should be split into smaller groups in a logical manner to facilitate their evaluation. Smaller groups are more manageable and the search for a pattern or patterns to make the assemblage more comprehensible as a whole becomes a less formidable task. While there are many ways to carry out such a division, for example by chronological period, characteristics of the weight pieces (Valmin 1936-1937: tables iv-viii), and determination of the repeating internal quotient (Bass 1967: 138), Petruso considers the division by site, especially in the case of clusters or sets of weights, to be the most logical (he himself broke down the corpus of Aegean weights by site to make that investigation more manageable). By their very nature, the Uluburun and Cape Gelidonya weight assemblages conform to this principle, as they were recovered from undisturbed, closed-context underwater sites. As noted earlier, the importance of these two assemblages cannot be overstated, because it is thus highly likely that the weight pieces constituted multiple sets in concurrent use and, as such, should represent the mathematical substratum of the system or systems on which they are based.

Petruso (1992: 8) agrees with Bass’s (1967) suggestion that at sites that were involved in international trade, the use of mass standards of various regions may be expected. At Ras Shamra/Ugarit, for example, Courtois (1990: 120) documents at least six different mass standards. For this reason, we have followed Bass in our investigation of the balance weights from Uluburun and have entertained the idea that several contemporaneous standards could have been in use on board the ship to facilitate transactions with foreign centers on their own metrical terms.

Yet the division of a corpus of weights into smaller, more manageable groups must be made logically. To force a well-preserved weight piece into a given system when its mass, and hence its denomination, is clearly an impractical or unlikely unit, is to jeopardize the credibility of one’s analysis. Consequently, Petruso (1992: 8) states that one cannot accept Bass’s attribution of many of the Cape Gelidonya balance
weight pieces to a specific system simply because they are divisible by the same integer; other, more significant rules, such as convenience and practicability, dictate the design and production of ancient metrical systems. In dealing with the shipwreck weight assemblages, therefore, I have first attempted to attribute only the most obvious members to norms. Only then have I have addressed the weights that do not readily fit a standard, by searching for internal patterns among them and parallel patterns elsewhere.

2) For reasons already stated, I have taken stone balance weights to be more reliable representations of their original masses than are weights of metal, and have used only well-preserved stone weight pieces in attempting to determine the original unit mass of a weight system. In this principle, I follow Petrie (1926: 3) and Petruso (1992: 9). It is obvious that cleaned stone weights are likely to weigh either the same as they did originally, or slightly less in the case of minor physical damage. Metal weights, on the other hand, seldom retain their original mass, as they are susceptible to chemical alteration by oxidation (corrosion) and/or leaching.

In the catalog of the balance weights from the two shipwrecks (Appendix C and D), weight specimens that are obviously underweight due to physical damage or missing components (i.e., lead plugs, lead cores, or metal straps) have been designated with a minus sign (-) following their masses. With the possible exception of one hematite weight that is provided with a tin (?) suspension loop, KW 2001 (W 106), no shipwreck balance weight is overweight. The increased mass of KW 2001 (W 106), due to some encrustation adhering to its corroded suspension loop, therefore, has been marked with a plus sign (+) following its mass. In the case of certain incomplete or physically damaged weights, the damaged areas were restored and the weight pieces's original mass was calculated with the help of a hydraulic balance. With metal weight pieces, again their volumes were calculated with aid of a hydraulic balance and their original masses estimated by using a conservative value for the specific gravity of sand-cast bronze (see Appendix B). The mass values of such
weight pieces are followed by (cal.) for calculated and (est.) for estimated.

3) Because it is impossible to know precisely how ancient balance weights were duplicated, none of the balance weight pieces of like material whose preservation allows for the accurate determination of their original masses are considered more accurate than any other. This follows Hemmy (1931: 589) and Petruso (1992: 9).

4) The simpler explanation will be preferred over the more complex. Petruso (1992: 9) states that “one balance weight does not and cannot in itself establish the use of an entire system at a site” and, within reason, this view may be extended to incorporate even several weight pieces, especially those of small or fractional denominations whose attributions cannot always be made with certainty. Following Petruso, therefore, I shall resist the temptation to argue for the existence of multiple mass standards merely to accommodate isolated problematic balance weights. Instead, considerable effort will be made to keep the analysis simple and the attributions to particular systems credible. It will be shown later that, in fact, the great majority of the balance weights from both shipwrecks may be easily attributed to a single decimal system whose unit mass is ca. 9.3-9.4 g.

5) The relationships among the balance weight pieces in a particular system should be based on simple, logical, and practical multiples of the standard, as asserted by Petrie (1926: 7). Petruso (1992: 9) agrees with Petrie and indicates that there is little reason to doubt this supposition. Nor have studies of extinct ancient weight systems from other parts of the Indo-European and non-Indo-European worlds since Petrie’s time produced any documentation to the contrary.

Statistical (Quantal) Analysis

Among the most potent criticisms of so much early work in historical metrology is that, too often, a very limited number of possible values were selected for consideration, and selectively so. But in recent years, the field of historical metrology has benefitted from new tools that now make its study far more objective. In
particular, sophisticated statistical techniques have been developed for what is usually called quantal analysis (Kendall 1974), which builds primarily on Broadbent's (1955) simple proposition that any member $X$ of a set of observed measurements, if it is indeed quantal (i.e., evenly divisible by the standard unit of the set), will be the product of a whole number $m$ and the quantum $q$, distorted by some error $e$:

$$i.e., \quad X = mq \pm e$$

"Broadbent’s contribution was to emphasize the need for more rigorous examination of a wide variety of possible values within specified limits, in order to see how well whole-number multiples of each potential quantum fit the observed set of measurements overall" (the "best" value being taken as the one that fits with the least total error) (Cherry 1983: 53). Kendall’s formula (see Appendix A) allows for the evaluation of the statistical viability of each hypothetical quantum as a possible standard unit for a population as a whole. In other words, the likelihood of each proposed hypothetical unit representing the common standard unit mass for a population of weights is tested by the formula. Thus, the test result produces a specific value that most likely represents the standard unit mass for the set.

The most comprehensive use of this approach in the analysis of prehistoric weights was made by Petruso (1992) in his milestone analysis of lead balance weights from the Aegean. Thanks to him, it is difficult to envision future analyses of ancient balance weights that will not follow his established principles of study. As Petruso (1992: 15) himself has noted, “the potential for this explicitly quantitative approach is great, especially as regards the recovery of systems whose balance weights bear no denominational markings.” He describes the approach as follows: “Given a population of measurements (e.g. spans, masses, volumes) of archaeological materials (e.g., architecture, balance weights, pots) that (a) can be chronologically and geographically isolated, and (b) are suspected of having been based on an absolute unit, the metrologist tests a wide variety of candidates for that unit, and ranks them in order of
their viability. So stated, the problem may be expressed in purely quantititative terms; what is needed, then, is a purely mathematical test whose credibility is by definition independent of either the existence of historically plausible preconceived units (i.e., units borrowed from elsewhere) or mere demonstrations of 'goodness-of-fit' of any particular unit chosen on intuitive grounds. In short, such an approach seeks to eliminate the intuitive element in the isolation of a standard unit—which may be referred to as a 'quantum'—by appealing to statistical demonstrability; it seeks to provide a mathematical answer to a mathematical problem, quite exclusive of other lines of evidence (Petruso 1992: 15-16)."

The set of data is processed according to the following formula:

\[
\varphi(\tau) = \sqrt{\frac{N}{n}} \sum_{j=1}^{N} \cos(2\pi X_j \tau)
\]

where \(N\) is the size of the population (in our case, the number of balance weights used in the analysis); \(X_j\) is a single observation (in our case, the mass of each balance weight); \(\tau\) is the reciprocal of a tested quantum; and \(\varphi(\tau)\) is a positive or negative relative error term. Those tested quanta (\(X\)) that return the highest positive values for \(\varphi(\tau)\) are the best candidates, on purely mathematical grounds, for the units on which the population is based. It should be noted that ancient balance weights comprise perhaps the single most important collection of artifacts suited for analysis by Kendall's formula, in that there is no doubt that the weights were quantally configured, with the possible exception of objects misidentified as weights. In Petruso's own words (1992: 16), "we need not hesitate about whether our specimens are quantal, but need to concern ourselves only with what the values of the quanta were."

For example, of the 55 balance weights cataloged from Ayia Irini, Petruso eliminated ten damaged or corroded weights and subjected the remaining 45 pieces to a quantal search according to the formula devised by Kendall. The value of 31.27 g produced the highest positive \(\varphi(\tau)\) value (the highest peak as plotted on a graph).
Naturally, it is independent of all evidence that could influence determination of the standard unit(s) in use at Ayia Irini. But in fact, the quantal search had isolated a value corresponding to only one-half of the actual standard unit of mass, whose presence was indicated by the marks borne by some of the lead weights. Kendall’s formula, therefore, reveals the statistically most viable quantum for a given population, which may actually represent only a fraction or, by extension, a multiple of the standard unit being sought. Petruso rightly cautions that “...neither the purely intuitive nor the purely quantitative approach to the data that concerns us is sufficient in and of itself to explain the subtleties of prehistoric Aegean weight metrology...It is by no means impossible to reconcile the two ostensibly antithetical approaches; indeed, it would be perverse not to attempt to do so (Petruso 1992: 16).”

To conclude, the analysis that follows is founded upon no preconceptions. The primary goal is simply to understand the mechanics of ancient weight mensuration used on the Uluburun and Cape Gelidonya shipwrecks. It is hoped that the study will stimulate further research and contribute to the understanding of the economic activities of the Late Bronze Age maritime trader.
CHAPTER II

WEIGHT STANDARDS OF THE

BRONZE AGE EASTERN MEDITERRANEAN

To put into proper context the weight standards that may be represented in the Uluburun and Cape Gelidonya balance weight assemblages, we must briefly examine the various mass standards used in the Eastern Mediterranean during the Bronze Age, and specifically the Late Bronze Age.

The origins of weights and measures are thought to date to the Paleolithic period, to a time long before people became livestock herders and farmers (Powell 1992: 897). Some of the first weight pieces were most probably naturally shaped or polished pebbles, stones, and cobbles gathered and used with minimal modification. The use of pieces of stone for weighing can, in fact, be traced to at least as early as the Early Bronze Age, when weight pieces were quite literally termed "stones" (Akkadian abimu). Consequently, thousands of stone weight specimens have been recovered from all over the eastern Mediterranean and its hinterlands, yet only a small proportion have been subjected to rigorous scientific scrutiny. With the exception of those of Egypt and Mesopotamia, and to a lesser extent Ebla, Alalakh, and Ugarit, there is little evidence to reveal how mass standards were structured and utilized. The workings of those systems, therefore, have been mostly hypothesized through analysis of the existing weight specimens themselves, which has sometimes resulted in erroneous or imprecise results.

One of the chief difficulties encountered in studying ancient weight pieces is that, due to the technological constraints of ancient balances themselves, the deviation of a weight’s mass from its intended value increases as the weight’s mass decreases. In other words, the ancients had greater difficulty in maintaining precision in smaller denominations than in larger ones. It should be remembered that even most modern weight pieces have a margin of error of ± 5% or more, but even so, it appears ancient
weights did not achieve even this degree of precision. Modern measures are also characterized by their standardization, whereas the ancients encountered great difficulties in defining units of mass due to the absence of standardized systems. Needless to say, this difficulty was compounded when inter-cultural and diachronic mass standards were involved. For these reasons, ancient equivalents of mass standards are usually just rough approximations. As a result, unless a small weight is an element of a specific weight set whose norm can be derived confidently from the larger denominations in the set, correct interpretation of a small weight piece becomes almost a matter of chance. Near Eastern weight measures, in descending order, are the talent, mina, and shekel, with additional fractional denominations of lesser consequence.

The talent (from the Greek talanton [τάλαντον]) probably customarily represented the maximum amount of weight, or "load," that could be shouldered comfortably by one man, and was in the vicinity of 30 kg. This is suggested by the etymologies of the Akkadian biltu and its Sumerian equivalent, GUN, which may be translated simply as "load" (Powell 1973: 209; 1992: 905; Karwiese 1990: 22). The theory that the talent was sexagesimally structured (i.e., consisted of 60 minas of 60 shekels each), and had been known and accepted since the Hellenistic period, remained unchanged in western metrological theory until modern times (Viedebantt 1917: 73, n. 4). The Near Eastern evidence for this is equivocal, however (Powell 1992: 905). The Babylonian talent comprised 60 minas of 60 shekels each, or 3,600 shekels, but west of the Euphrates it seems generally to have been made up of 3,000 shekels by the Late Bronze Age, as attested at Ugarit and Alalakh (Parise 1970-1971: 14-15; Zaccagnini 1978).

In any case, at least by the Late Bronze Age the talent appears to have acquired a trade-weight status reflected in the copper "oxhide" ingots that are found throughout the eastern Mediterranean and even as far as Sardinia in the west. Perhaps reflecting to some extent the Sumero-Babylonian "load" of ca. 30 kg, many of these
copper ingots are in the 28-30 kg range, which suggests they were not closely controlled equivalents of the talent mass, but rather reflect some attempt to approximate the talent to facilitate reckoning (Parise 1968: 128; Zaccagnini 1986: 414-15). Final transactions would have undoubtedly required precise weighing of each ingot. The 19 copper oxhide ingots found at Ayia Triada, on Crete, for example weigh between 27 kg and 32 kg, with seven ingots tightly clustering around the value of 29.4 - 29.5 kg (Parise 1968: 119; Petruso 1992: 18). Of the 34 originally complete copper oxhide ingots on the Cape Gelidonya ship, only 29 of them are sufficiently intact for comparative purposes. Their weights range from 11.6 kg to 25.9 kg, with nearly a quarter of them clustering between 19 kg and 20 kg (6 specimens) and another quarter between 21 kg and 22 kg (7 specimens) (Bass 1967: 53, 57). As such, these ingots are significantly lighter than those from Ayia Triaha, but it is impossible to determine how much mass loss each Cape Gelidonya ingot has suffered from more than three millennia of submersion in sea water.

The typical sexagesimal mina is attested at Ebla in the third millennium, but during the subsequent millennium it seems to mostly disappear as a unit west of the Euphrates (Powell 1992: 906). Texts from both Alalakh and Ugarit, for example, contain sums indicated in hundreds and thousands of shekels without reference to the mina (Powell 1992: 906). There has been considerable debate as to whether, during the second millennium, the Ugaritic or western mina contained 50 shekels or 60. The evidence to date strongly favors the former (Parise 1970-1971; Zaccagnini 1978).

From the Assyrian evidence it certainly appears that by the first millennium, 2 Mesopotamian minas, or 120 shekels, had become equated with 100 western shekels, thereby distinguishing the “strong” (Akkadian dammu) shekel and mina from the “lesser/lighter” (Akkadian gallu) Mesopotamian shekel and mina (Powell 1992: 906). As there are no references to an analogous “strong” talent (60 minas of 60 heavy or “strong” shekels each), it seems that the western mina consisted of 50 shekels. Yet, as the Old Testament treats the shekel as the primary unit of mass, and similar uses of the
shekel are abundantly documented in texts from Ugarit (Heltzer 1978: 17-73) and Alalakh (Zaccagnini 1978; Parise 1970-1971: 14, n. 11), whether the Ugaritic and other western minas contained 50 or 60 shekels may not be pertinent (Powell 1992: 906). The “strong” norms attested in Assyria only during the first millennium (and never in Babylonia) may only have been a mechanism to facilitate, probably for tax purposes, conversion of mass norms of the western decimal system into those of the Mesopotamian sexagesimal system (Powell 1992: 906). The shekel is the smallest integer denomination and, as a result, the one that was most subject to variation in its absolute mass.

In his monumental study of ancient weights and measures, Petrie isolated eight mass standards used in Egypt during Dynastic times. These standards he called the peyem (pym, the Philistine shekel), the daric (Mesopotamian), the stater, the qedet (qdt), the necef (ngf), the khoirānē, the beqa (Egyptian gold, or mub, standard), and the selā (the Phoenician shekel) (Petrie 1926: 1-2). Of these, Petrie considered only the qedet and the beqa to be indigenous to Egypt, with those remaining having been introduced from abroad, mostly the Near East. This scenario, of course, is to be expected, as international trade relations would seem to necessitate the presence of foreign mass standards in places where trade in imported and exported goods prevailed, especially in coastal towns and cities. The names of three of these mass standards have been found inscribed on balance weight specimens from Palestine: the necef, the peyem, and the beqa; another standard, signified by the monogram XO, was named the khoirānē by Petrie (1926). Petrie noted, however, that the different examples of these mass standards show so many variations that, when taken together, they appear to form a continuous, overlapping series. Thus, it becomes extremely difficult to determine with certainty if a weight piece represents, for example, a heavy member of one standard or, conversely, a light one of a slightly heavier standard. Petrie distinguished the different standards by devising a system of classification based on consideration of the masses, multiples, markings and inscriptions (if any), varieties,
and materials of over four thousand individual weight pieces. During this process he restricted himself to material facts only, and did not allow the influence of theories based on the interrelation of standards, a popular view promoted at the time by comparative metrologists (see The Mesopotamian Mina below). Petrie (1926) also noted that because the term shekel was used in many different mass systems, it was necessary to refer to the various standards by their specific names in order to avoid confusion. These eight mass standards, as well as two additional standards, will be examined briefly in order of ascending mass.

**The Peyem (Pym) Standard**

To judge from the distribution of weight specimens that have been found inscribed with the characters *pym*, the *peyem* mass standard, along with the *necef*, to which it seems to be related, seems to have been confined primarily to Palestine. Although the meaning of *peyem* is uncertain, it is not derived from Sumerian, but could be of Philistine origin (Powell 1992: 906). Some have suggested it is a Semitic expression for “two-thirds” (Pilcher 1916; Diringer 1942: 87-88; Ben-David 1979: 35-37). As we will see below, the value of the *peyem* lies roughly in the 7.2 g to 8 g range, so it is not impossible that the *peyem* represents “two-thirds” of a shekel norm in the ca. 11 g - 13 g range, but neither the philological nor the metrological evidence conclusively supports this supposition, and such a metrological theory would be tenuous at best (Ben-David 1979; *contra* Parise 1984: 129, n. 11; Powell 1992: 906). The “Economic Text” (RS 1957.701 [KTU 4.709]) from Ras Shamra/Ugarit is the source of this controversy. Liverani (1972: 195) interpreted the text as equating the talent used at Ashdod (in Palestine) with 2,400 shekels, each weighing 7.52 g, with 1 mina = 40 shekels (thus 60 minas). From the same text, Ben-David (1979: 31-41) calculated the Ashdod talent as 2,500 shekels with 50 shekels per mina. Ben-David also cataloged 28 inscribed *peyem* weight specimens from Ashdod that average 7.81 g each (*contra* the average of 7.78 g he reports). In seeking the norm of the group he
used the midpoint value theory where, for a group comprising a limited number of presumably like elements, a better representation of their intended value may be the average of the highest and lowest values than the average of all the values of the group. Accordingly, Ben-David (1979: 31-41) calculated a midpoint value of 7.89 g for the peyem, which generates an Ashdod talent of 19.725 kg (7.89 g x 50 x 50), and suggested a peyem norm of ca. 8.0 g.

Another look at the "Economic Text" reveals that 7 talents of Ashdod appear to be equated with 5 talents and 1,800 shekels of Ugarit (i.e., 21,000 Ashdod shekels = 16,800 Ugaritic shekels). If this is indeed the case, then 5 shekels of Ashdod equal 4 shekels of Ugarit (Powell 1992: 906). In other words, using the average value of ca. 9.4 g for the Ugaritic/Syrian shekel (see The Ugaritic Shekel below), one obtains for the Ashdod shekel a mass of 7.5 g ([4 x 9.4 g] ÷ 5 = 7.5 g), which approximates the value of the peyem. The peyem, therefore, denotes the shekel of Ashdod, which during the Late Bronze Age seems to have been about 80% of the Ugaritic shekel. As that shekel was in the ca. 9-10 g range (Ben-David 1979: 30-42; Courtois 1990: 122), it would appear that the peyem should fall between 7.2 g and 8 g. Petrie (1926: 8-9) averaged three weight specimens from Palestine and obtained 7.57 g for the unit mass of the standard, and 7.50 g for the average of 12 marked weights from Egypt. Based on these values and comparisons with other weight pieces, he established the limits of the peyem standard as 7.54 g and 7.89 g. Courtois (1990: 122) notes that only 3.5% of the 566 weight pieces from Ras Shamra (Ugarit) seem to correspond to this standard (his Eblite shekel of 7.83 g).

The Mesopotamian Standard

According to Petrie (1926: 11), the Mesopotamian weight standard, which he named the daric, appears to have been used from prehistoric times onward and was introduced into Egypt by eastern invaders of the Gerzean period (second half of the fourth millennium B.C.E.). Metrology in Babylonia during the third millennium
B.C.E. is noted for the presence of many localized variations on the Sumerian sexagesimal system. During the last part of that millennium (ca. 2200 B.C.E.), however, measures of length, area, volume, and mass appear to have been gradually incorporated into an integrated system of measures. This system was solidly established by the end of the Ur III period (ca. 2000 B.C.E.) and continued as the standard system of calculation and accounting until the end of the Old Babylonian period (ca. 1600 B.C.E.) (Powell 1992: 897). The subsequent period (ca. 1600-650 B.C.E.) witnessed a restructuring of the mass system, and while it preserved in full its sexagesimal factoring, it also incorporated the Semitic system of unit fractions, which were known at least since the Old Babylonian period. The new fractions included 1/4, 1/5, 1/6, 1/8, 1/12, and 1/24, the last being identified with the seed of the carob tree (Akkadian gerû; gerah or grh in the Old Testament), hence the modern "carat." The system's primary unit of mass was the mina (Akkadian manû) of about 500 g, consisting of 60 shekels (šiqlu) or 10,800 barley corns (Powell 1992: 897).

In upper Mesopotamia, a strong non-Babylonian influence is in evidence at least by 1800 B.C.E. Here, the typical sexagesimal structure was being influenced by the decimal factoring in use on the Syro-Palestinian coast, a system probably inherited from the Egyptians. By the first millennium B.C.E., most sexagesimal structures in Assyria had been modified to incorporate the decimal system. Petrie (1926: 11) places the lower and upper limits of the daric standard at 8.08 g and 8.63 g, with a mina comprising 60 shekels and multiples consistent with the Egyptian decimal and Mesopotamian sexagesimal systems. Courtois (1990: 122) attributes 110 (20 %) of the weight pieces found at Ras Shamra (Ugarit) to this mass standard, and gives its mass range 8 g - 8.5 g (but as 8 g - 8.4 g on p. 120).

**The Stater Standard**

Named after the well known gold staters of Philip of Macedon, the early name for this standard is not known, even though it appears to have been used in Egypt
since the Old Kingdom. Placed between the Mesopotamian shekel and the Egyptian qedet in mass, it has been confused with the two standards, according to Petrie (1926: 12-13). For this reason, its existence has even been denied. Two early marked examples, however, are far too light even for the lightest qedet, and too heavy to fit into the daric standard. Its delimitation is about 8.71 g to 8.93 g, as given by Petrie, who notes that on the whole, the stater balance weights are of rounded shapes, seldom finely crafted, and often badly or ill-defined, whereas the qedet is the most well cut of any group, with generally clean forms and sharp edges. This being the case, and given the exceedingly common use of the qedet (see below), one cannot but help wonder if many of the balance weights assigned to the stater standard may, in fact, represent poorly crafted and/or provincial forms of the qedet that are somewhat lighter. There are 74 (ca. 13 %) weight pieces from Ras Shamra (Ugarit) that appear to conform to a shekel standard in the range of 8.7 to 8.8 g (Courtois 1990: 120).

**The Qedet (Qdt) Standard**

The basic unit of mass in Egypt during the Old and Middle Kingdoms was known as the deben (dbn). It seems to have weighed ca. 13.6 g and to have incorporated a double standard for weighing copper. In the New Kingdom, the deben weighed ca. 93 g and was divided into 10 qedet (qdt) of ca. 9.3 g each. (The term deben was applied to 10-unit multiples of other standards as well, and in the Twenty-sixth Dynasty 10 deben constituted 1 sep.) The qedet was by far the most commonly used standard in Egypt and the basis for nearly all expressions of weight from the Eighteenth Dynasty onward. Its history is not well defined, but its earliest use appears to be at the beginning of the First Dynasty in Egypt, and like the beqa, it is believed to have been indigenous to Egypt. Petrie (1926: 13) established the qedet mass limits as 8.97 g and 9.86 g. See also *The Ugaritic Shekel* below.

**The Ugaritic Standard**

The major unit of mass used in western Syria and at Ugarit was the shekel,
which, as at Alalakh, was based on the decimal mode. Its value appears to have been in the vicinity of 9.4 g (Arnaud 1967: 61), and almost certainly derived from the Egyptian *qedet*.

Excavations since 1929 at Ugarit have turned up a remarkable collection of some 600 weight pieces, for which the masses of 566 are known (Courtois 1990: 119). This impressive corpus of weights has allowed the determination of at least some of the various mass systems used in this cosmopolitan city, but the great majority of the specimens, some 314 (ca. 56%), correspond to the Ugaritic shekel, whose mass range has been given as 9 g to 9.9 g (Courtois 1990: 122). Based on these pieces, the following multiple and fractional denominations have been discerned: 3000, 1000, 500, 300, 200, 100, 50, 40, 30, 20, 10, 5, 4, 3, 2, 1, 2/3, 1/2, 1/3, 1/4, and 1/8. The most frequently represented denominations are 2 (47 specimens), 10 (46 specimens), 1 (39 specimens), 5 (27 specimens), and 20 (25 specimens) (Courtois 1990: 122).

The relationship between the shekels in use at Ugarit, Kargamish (*peyem* mass range), and the Hittite Kingdom (*Petrie’s khoirînê*), may be summarized from Parise’s (1970-1971; 1989) important publications. Ugaritic text RS 11.732 equates the mass of a golden cup, previously determined to have weighed a Hittite mina of 40 shekels (11.75 g/shekel), to that of the Ugaritic mina of 50 shekels (9.4 g/shekel). Additionally, Ugaritic text RS 17.146, a piece of correspondence between the kings of Kargamish and Ugarit regarding the subject of murder of merchants, and text RS 17.158, exchanged between the kings of Kargamish and Ta’rkhudashshi regarding a verdict handed down by the former king for the death of a merchant subject of the latter king, both specify compensatory payments. This compensation to be paid is expressed in the first text as 3 minas of silver, and in the second as 180 shekels of silver. These two different standards used for expressing the compensation of silver to be paid require that they both represent the same quantity or mass of silver. As the Ugaritic mina comprises 50 shekels, then 3 Ugaritic minas, or 150 Ugaritic shekels,
corresponds to 180 Kargamish shekels, or 5 Ugaritic shekels is equal to 6 Kargamish shekels. From this it follows that a Kargamish shekel is about 7.83 g. The results of the above discussion may be summarized in conversion table 1 as follows (Courtois 1990: 123):

Table 1. Equivalences between the Ugarit, Kargamish, and Hittite Shekels.

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Mass (g)</th>
<th>Talent</th>
<th>Mina</th>
<th>Hittite Shekel</th>
<th>Ugaritic Shekel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talent</td>
<td>28,200</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mina</td>
<td>470</td>
<td>60</td>
<td>1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hittite Shekel</td>
<td>11.75</td>
<td>2400</td>
<td>40</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Ugaritic Shekel</td>
<td>9.4</td>
<td>3000</td>
<td>50</td>
<td>5/4</td>
<td>1</td>
</tr>
<tr>
<td>Kargamish Shekel</td>
<td>7.83</td>
<td>3600</td>
<td>60</td>
<td>3/2</td>
<td>6/5</td>
</tr>
</tbody>
</table>

In other words, mass equivalences in use in Late Bronze Age Syria can be described as follows: Hittite: Ugarit: Kargamish = 4:5:6. Of the 566 weight pieces with known masses from Ras Shamra (Ugarit), 314 (55 %) conform to this standard. Courtois (1990: 122) gives the range of its mass as 9 - 9.9 g.

The Necef (Nṣf) Standard

The nṣf-inscribed balance weights were recovered from a region that approximates the Biblical Kingdom of Judah. It is bounded on the west by the Mediterranean sea, on the east by the Jordan river, on the north by Jerusalem and areas immediately north, and on the south by Arad, a site that has yielded both peyem and necef weights (Ben-David 1979: 45). Although necef has been compared to the Arabic root nṣf, which generates words meaning "half," the basic meaning of necef may have been "divide into equal parts" (Powell 1992: 906). If so, then one-half of the “double shekel” suggested to occur during Assyrian times, supposedly represented by the necef, may be a non-existent standard (Powell 1992: 906). According to
Petrie's evidence from Egypt, the *necef* and the *qedet* appear to overlap in the range between 9.85 g and 9.98 g, and their distinction depends on the forms of the individual weights (Petrie 1926: 15). The *qedet* weight pieces were usually dome-topped and frequently domed from the base upward. The *necef* weight pieces were also commonly dome-topped, but with a sharp top edge, and only very rarely were they domed from the base upward (Petrie 1926: 15-16). Petrie established the limits of the *necef* standard at 9.91 g and 11.05 g, with a mean standard value of 10.11 g.

Ben-David (1979: 41-45) lists 36 inscribed *necef* weight specimens with a midpoint mass value of 9.71 g (*contra* the 9.179 g he indicates) and an average mass of 9.74 g (*contra* the 9.156 g he indicates), yielding roughly 10 g for the unit mass of the standard. Because the *peyem* and *necef* mass standards were used concurrently in the same general region, Ben-David submits a partial explanation for this seemingly unusual situation. He advances the idea that these norms must have represented gold and silver standards, respectively.

Being a heavier standard than the Mesopotamian shekel, then, it seems likely that the Palestinian weights inscribed with the character group *ñg̃*, which is also found in Ugaritic documents, represent the shekel norm of the Assyrian “strong” mina. Consequently, the *necef*, the Ugaritic shekel, and the Alalakh shekel, all in the 9-10 g range, correspond approximately to the 100th part of 2 Mesopotamian minas (Powell 1992: 906).

**The Hittite or Asia Minor Standard**

Some weight specimens, found mostly in Palestine (Petrie 1926: 16, mentions only one specimen from Egypt), bear a symbol that looks like an unfinished figure. It is usually interpreted as signifying a shekel, but the meaning is unclear (Powell 1992: 906). Petrie (1926: 16, 49) noted the apparent use of this standard in Egypt from the Old Kingdom onward and set its limits at 11.28 g and 11.66 g, with a mean value of 11.54 g. He also reported the similarity of this symbol to the Greek letters χ and ο (*kh*...
and o), thus perhaps the beginning of χοιρίνη = khoirînē, the Greek word for cowry. To corroborate this suggestion he listed a group of five cowry shells from Egypt, carved in gray syenite, that all appear to conform to the fractions and multiples of the unit. An interesting feature of some weights attributed to this standard is the use of Egyptian hieratic symbols to indicate the numbers 5, 10, 20, 30, and 40, which, it has been ventured, denote 4, 8, 16, 24, and 32 multiples of a norm in the 11-12 g range (Powell 1992: 906). This has been interpreted as describing the relationship between the basic unit or "shekel" of the norm and the Egyptian qedet as 10:8 (Powell 1992: 906, citing Aharoni 1966: 13-19). Consequently, taking 9.4 g as the value of the qedet, we find for the khoirînē shekel norm a mass value of ca. 11.8 g. While the masses of weight specimens attributed to this norm vary considerably, the unit mass value of 11.4 g serves fairly well for most applications. Even so, the precise workings of the system remain obscure. Due to textual evidence that relates the use of a norm of this mass by the Hittites, the norm is now more commonly known as the Asia Minor standard (Courtois 1990: 121). Courtois (1990: 122) attributes 40 (7 %) of the 566 weights from Ras Shamra (Ugarit) to this standard and gives its mass range as 11.2g - 11.8 g.

The Beqa Standard

This Egyptian standard is commonly known as the gold standard, the term deriving from three weight specimens found in Palestine that all bear the hieroglyph for the word beqa', gold. Petrie (1926: 17) gives the range for balance weights thus marked as 12.33 g - 13.99 g (12.74 g - 13.65 g). It is attested in Egypt far earlier than any other norm and may ultimately trace its origins to a foreign source, but to date it is one of only two standards regarded as apparently indigenous to Egypt. It is worth noting that the barrel form, often seen in all the other standards (and especially the Mesopotamian), is entirely absent from the beqa (Petrie 1926: 18).
The Sela (Phoenician) Standard

This well known standard is usually called the Phoenician (or Alexandrian) standard. Its sole distinctive name is *sela*, which later became the Jewish name for this shekel (Petrie 1926: 19). Petrie puts its mass between 13.98 g and 15.60 g and notes that, at least for those examples found in Egypt, about a quarter of them are irregularly formed weights.

The Aegean Standard

As there is probably at least one weight piece from the Uluburun shipwreck that is attributable to this system, it is included here. Based purely on mathematical evidence, that is to say the evaluation of the masses of 117 balance weights from the Aegean region, Petruso (1992: 60) isolated a system of mensuration with a standard of mass of ca. 61 g that appears to have been used widely during the Late Bronze Age on Crete, in the Cyclades, and at least in the southern Peloponnese. By using specific weights bearing signs that can be interpreted as denominational marks, Petruso was able to ground the system to a series of absolute masses, and the marked weights also have provided clues to the workings of the system. While the smaller marked denominations suggest that the standard unit was halved consecutively, the higher marked denominations indicate that they were obtained by consecutive doubling. Petruso thus proposed the following skeleton for the system (all absolute mass values are approximate):

1/18 unit = 3.36 g = 1/144 mina = 1/8640 talent
1/8 unit = 7.5 g
1/4 unit = 15 g
1/3 unit = 20.2 g = 1/24 mina = 1/1440 talent
1/2 unit = 30 g
1 unit = 61 g = 1/8 mina
2 units = 122 g = 1/4 mina
4 units = 244 g (242 g) = 1/120 talent
8 units = 488 g (483 g) = 1/60 talent
16 units = 976 g (967 g) = 2 minas = 1/30 talent
4870 units = 29,280 g (29,000 g) = 60 minas = 1 talent

The Minoan talent was therefore a sexagesimal multiple of its mina (Petruso 1992: 18-19). In addition to the system’s binary rendering of the unit, a duodecimal series of multiples is indicated by pieces marked as the denominations 1-1/2, 3, 6, 12, and 24.

While Petruso established the mass of the Aegean unit as ca. 61 g, upper and lower limits for the standard may be obtained from his published data. The lowest value for the unit is 54.5 g, the highest 67.6 g, which is much too broad a range. Perhaps more realistic limits may be determined by calculating the mean resultant unit for the balance weights from each site included in Petruso’s study. Accordingly, the lowest mean resultant unit is 59.6 g, given by the balance weights from Knossos, and the highest is 62.7 g, produced by those from Palaikastro. The average for the two is 61.2 g, while the average of the mean resultant unit for all sites studied by Petruso is 61.1 g. This is virtually Petruso’s proposed value for the unit mass of the Aegean standard based on quantal analysis: ca. 61 g.

The foregoing nine mass standards, with all norms but the Aegean as described and delimited by Petrie (1926: 20-21), are given in table 2.
Table 2. Petrie’s eight mass standards, the Ugaritic shekel, and the Aegean standard as established by Petruso.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Mass Range</th>
<th>Shekels per Mina</th>
<th>Mina Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peyem</td>
<td>7.41 g - 8.12 g*</td>
<td>50</td>
<td>370.5 g - 406 g*</td>
</tr>
<tr>
<td></td>
<td>7.39 g - 8.04 g*</td>
<td></td>
<td>369.5 g - 402 g*</td>
</tr>
<tr>
<td></td>
<td>7.83 g*</td>
<td></td>
<td>391.5 g*</td>
</tr>
<tr>
<td>Mesopotamian</td>
<td>8.12 g - 8.61 g*</td>
<td>60</td>
<td>487.2 g - 516.6 g*</td>
</tr>
<tr>
<td></td>
<td>8.10 g - 8.29 g*</td>
<td></td>
<td>486 g - 497.4 g*</td>
</tr>
<tr>
<td></td>
<td>8 g - 8.5 g*</td>
<td></td>
<td>480 g - 510 g*</td>
</tr>
<tr>
<td>Stater</td>
<td>8.61 g - 8.94 g*</td>
<td>50</td>
<td>430.5 g - 447 g*</td>
</tr>
<tr>
<td></td>
<td>8.59 g - 8.89 g*</td>
<td></td>
<td>429.5 g - 444.5 g*</td>
</tr>
<tr>
<td></td>
<td>8.7 g - 8.8 g*</td>
<td></td>
<td>435 g - 440 g*</td>
</tr>
<tr>
<td>Qedet</td>
<td>8.94 g - 9.91 g*</td>
<td>50</td>
<td>447 g - 495.5 g*</td>
</tr>
<tr>
<td></td>
<td>8.96 g - 9.78 g*</td>
<td></td>
<td>448 g - 489 g*</td>
</tr>
<tr>
<td>Ugaritic Shekel</td>
<td>9 g - 9.9 g*</td>
<td>50</td>
<td>450 g - 495 g*</td>
</tr>
<tr>
<td>Necef</td>
<td>9.91 g - 11.05 g*</td>
<td>50</td>
<td>495.5 g - 552.5 g*</td>
</tr>
<tr>
<td></td>
<td>9.91 g - 10.56 g*</td>
<td></td>
<td>495.5 g - 528 g*</td>
</tr>
<tr>
<td>Asia Minor or</td>
<td>11.05 g - 12.35 g*</td>
<td>50</td>
<td>552.5 g - 617.5 g*</td>
</tr>
<tr>
<td>Hittite (Khoirînê)</td>
<td>11.48 g - 11.80 g*</td>
<td></td>
<td>574 g - 590 g*</td>
</tr>
<tr>
<td></td>
<td>11.2 g - 11.8 g*</td>
<td></td>
<td>560 g - 590 g*</td>
</tr>
<tr>
<td>Beqa</td>
<td>12.35 g - 13.72 g*</td>
<td>50</td>
<td>617.5 g - 686 g*</td>
</tr>
<tr>
<td></td>
<td>12.31 g - 13.61 g*</td>
<td></td>
<td>615.5 g - 680.5 g*</td>
</tr>
<tr>
<td>Sela</td>
<td>13.72 g - 14.82 g*</td>
<td>25</td>
<td>343 g - 370.5 g*</td>
</tr>
<tr>
<td></td>
<td>14.00 g - 14.38 g*</td>
<td></td>
<td>350 g - 359.5 g*</td>
</tr>
<tr>
<td>Aegean</td>
<td>ca. 61 g*</td>
<td>8</td>
<td>488 g</td>
</tr>
</tbody>
</table>

* values assigned by Petrie (1926: 7)
* values assigned by Hemmy (1937: 52)
*values assigned by Courtois (1990: 120, 122)
† value from Petruso (1992: 61)

The History of Near Eastern Metrology: Two Case Studies

Speculation and debate concerning the absolute mass values of ancient metrical standards, their interrelationships, and the precision with which standard unit masses should be expressed, have resulted in the voluminous publication of material, not all of
which has advanced the understanding of ancient metrology. It is quite clear, however, especially with advances recently made in the field (see Chapter I and Appendix A), that the determination of the common mass standards used in the Late Bronze Age eastern Mediterranean can best be accomplished through the detailed examination of ancient balance weight groups themselves. To illustrate, it may be helpful to examine briefly the development and evolution of ancient metrology. As the topic is vast and not our focus here, two case studies will serve our purpose. That of Mesopotamian mina is largely a summary of Powell (1979), while that of the Egyptian qedet has benefitted greatly from Petruso (1992).

The Mesopotamian Mina. One of the most popular methods used by early metrologists to determine norms was known as comparative metrology. Stated very loosely, comparative metrology assumed that most or all metrological systems are interrelated, and so attempted to discover the relationships that existed among the systems in order to define once-existing norms (Powell 1979: 74-75). It had evolved out of the dire need to resolve the difficulties and confusion generated by the multiplicity of Mesopotamian mass standards. Those subscribing to this school tried to alleviate the problem to some extent by attempting to associate the predominant Mesopotamian mass standards with those used in other eastern Mediterranean countries and elsewhere, thereby reducing the number of standards to more comprehensible proportions.

With the 1838 publication of the classical scholar August Böckh's trend-setting work, the foundations of comparative metrology were established. Böckh's work had such a profound impact on subsequent studies in ancient metrology that, by the late nineteenth century, it had become the preeminent school of metrological thought (Powell 1979: 75). Carl Friedrich Lehmann-Haupt probably represents the last important student of the school. His studies incorporated the fundamentals of Böckh's work and served as the beacon of metrological investigations from 1888 onward (Powell 1979: 75). In 1907, however, F.H. Weissbach challenged the methodology
employed by Lehmann-Haupt, which resulted in a decade-long exchange of publications between the two scholars (Powell 1979: 76). Even so, Weissbach's perceptive critique in fact signaled the demise of comparative metrology as the acceptable method for investigating ancient mass standards. This state of affairs was thoroughly reviewed by Oskar Viedebanttt (1917; 1923), who sided with Weissbach. Yet neither Weissbach nor Viedebanttt dismissed the value of comparative metrology altogether. In fact, they concluded that it would be valuable after the difficulties encountered in determining the absolute standards of various mass standards had been resolved and a more secure basis for comparisons were established (Powell 1979: 76).

After more than 50 years of subsequent work, however, at least one scholar held the conviction that, at least for Mesopotamia, "the specialized task still remains to be completed and, until then, comparison of Mesopotamian norms with those of other countries can be of little value" (Powell 1979: 76).

As the problem of identifying and determining ancient mass standards still awaited a solution, the demise of comparative metrology opened doors to the application of new methods. Weissbach was prepared to proceed empirically, and by suggesting that the gold tablet of 167 g discovered at Khorsabad represented precisely 1/3 of a mina (Powell 1979: 76), he attempted to establish the mina standard of Sargon II of Assyria at 501 g. But this was only one norm among a myriad attested for Mesopotamia. Eventually, F. Thureau-Dangin claimed to have discovered the parent norm of Mesopotamia, which he believed to have originated with the Sumerians (Powell 1979: 77). He argued that it was based on the mass of a water cube whose sides were equal in length to the so-called "cubit of Gudea." This cubit he fixed at ca. 49.5 cm, which produced a water cube with a mass of 121,287.37 g. He claimed to find confirmation for this figure in the great uninscribed bronze lions from Khorsabad (mass = 60,303 g or 120 minas or 2 talents) and Susa (mass = 121,543 g or 240 minas or 4 talents) that totaled 360 minas, or 6 talents. The two bronze lions gave an average mina mass of 505.1277 g and an average talent mass of 30,307.666, which,
when quadrupled, yields 121,230.666 g, the approximate mass of the larger Susa lion. The cube root of this number is 49.492282, essentially the length of the cubit of Gudea.

This hypothesis Thureau-Dangin brilliantly supported with textual evidence (Powell 1979: 77). The text in question mentions the daily delivery of grain to a temple in Uruk, where its quantity is expressed in terms of a sūt of 10 minas. Thureau-Dangin reasoned that as the text is from Neo-Babylonian times, the sūt should consist of 6 qa. Moreover, he stated that the indicated quantity must correspond to a volume, and thus weight of water, because that of barley varies between 57 and 76 kilograms per hectoliter, which would be much too heavy. Therefore, the weight and therefore volume of a qa was calculated as follows (Powell 1979: 77):

\[ 6 \text{ qa} = 1 \text{ sūt} = 10 \text{ minas} = 10 \times 505.127 \text{ g} = 5.05 \text{ kg} \]

\[ 1 \text{ qa} = 5.05 \text{ kg} / 6 = 0.842 \text{ kg or liter} \]

Also:

1 talent = 10 minas × 6 = 6 qa × 6 = 5.05 kg × 6 = 30.300 kg

Further, if the value of qa remained unchanged over two millennia, the mass unit of the gur-sag-gal used in Presargonic Lagash would be equal to the weight of the Susa lion, or four talents (Powell 1979: 77). It should be noted that Thureau-Dangin’s efforts to associate the Mesopotamian standard of mass to other mass standards, in itself, was not original, though the eloquence with which he presented his evidence made it the most convincing attempt of its kind (Powell 1979: 77). A.E. Berriman (1955a: 193-201) suggested some 40 years ago that the Marduk-šar-ilani weight of Nebuchadnezzar, a weight piece of 978.3 g first published in 1891 (Sayce 1891: 568), may be interpreted as 2 French livres of 498.5 g, and that a talent of 60 such livres would equal the mass of a water cube measuring 1 ancient Greek foot per side. Berriman was not only attempting to establish the absolute mass standard of the mina as represented by the Nebuchadnezzar weight, but also to associate this mass
standard to the ancient Greek foot and the French livre. While Berriman's works include many other interesting and noteworthy metrological relationships, mostly supported by his fascination for mathematical calculations, his approach, in fact, still follows the methodology of comparative metrology.

It may be of interest to note here that the misinterpretation of the same Nebuchadnezzar weight by Lehmann-Haupt (1893: 179 ff, and passim) had led to the fundamentally baseless assertion of the existence of a "light" and a "heavy" Babylonian mina (Powell 1979: 75). There are many other noteworthy citations of relationships between the Mesopotamian mina and other standards of mensuration, but the examples given should suffice to illustrate the point. Such observations have now been cited for over half a century in various works dealing with the metrology of Mesopotamian masses. Yet: they have demonstrated that the Mesopotamian mina appears to vary only slightly in mass between 498 grams and 506 grams; Powell's (1979) study of approximately 2,000 weight pieces has indicated for the mina a mean value of 504 grams.

But, what are the real metrological implications of such observations? The arguments used to establish the Mesopotamian standard of mass based on ancient length measurements, such as that of the so-called cubit of Gudea, cannot be considered valid because they assume that the standards of length remained absolutely unchanged over time, even though there is no reason to believe that this was the case (Powell 1979: 78). Similarly, the proposed correlation between the talent and the measurement of volume (qa = 36 sīla) used in Presargonic Lagash holds only if the Neo-Babylonian qa and the Presargonic Lagashian sīla of two millennia earlier remained identical in volume. Nor does Thureau-Dangin's suggestion indicate that the Sumerians established a relationship between their standards of mass to the mass of a water cube of specific dimensions. Therefore, these observed relationships cannot really be taken to prove the norms of the Mesopotamian mina (or of the sīla/qa). Because the knowledge that water is of relatively consistent density is elementary,
however, it is certainly not inconceivable that such a relationship existed during
Presargonic times. Indeed, they probably are pertinent to the observation that the
mina norm remains relatively unchanged for over two millennia, from the Presargonic
period until the time of Darius the Great (Powell 1979: 78). Powell comments,
however, that Mesopotamian metrology is not yet in a position to evaluate the
implications of any particular observation, and that “like many of the results of the
comparative method, it remains, from lack of supporting evidence, hanging in the void
as an interesting but not compelling observation” (Powell 1979: 78).

The dubious results obtained for the norms of ancient mass standards by
students of comparative metrology eventually led to statistical evaluations of the
available archaeological material evidence. The first successful attempt at formulating
a statistical methodology for establishing the norms of ancient weight pieces was made
by Hemmy (1935: 83-93), who assumed that ancient balances tolerated (or
introduced) a considerable margin of error, and so analyzed his specimens by
application of the Law of Errors. As prerequisites for the proper application of his
methodology, Hemmy specified that there be a sufficiently large number of specimens
(at least 200), and that the mass of each weight piece in the study be determined to
within one-half of one percent (i.e., ± 0.005) of its original mass. Hemmy’s (1935: 89-
90) statistical analysis of weights coming from Mesopotamia has revealed shekel
norms of 7.575 g, 8.225 g, 8.45 g, 8.775 g, and 9.25 g, with the majority of specimens
conforming to the 8.225 g standard (54 %). A subsequent analysis by Hemmy (1937)
on the Petrie collection of weights has revealed shekel norms whose principle maxima
correspond to masses in the range of 8.20 g - 8.29 g, 8.75 g - 8.89 g, 9.46 g - 9.49 g,
13.34 g - 13.62 g, and 14.12 g. While no principle maxima are indicated for mass
values approximating the peyem and necef standards, the existence of which is
uncertain in the collection according to Hemmy, minor maxima in the range of 7.39 g -
7.65 g for the former standard, and 9.91 g - 10.56 g for the latter may be found. The
shekel norm in the range of ca. 11 g (Petrie’s khoirînē, or the “Hittite” shekel),
indicated by a minor maximum of 11.48 g, is also not well represented and its occurrence before the Eighteenth Dynasty seems uncertain (Hemmy 1937: 52-56). While conceding the usefulness of Hemmy’s approach in determining the most commonly used norms among a group of balance weights, Powell (1979: 79) notes that the diversity of Mesopotamian norms and the great time span represented by the weights actually require a much larger number of weights than Hemmy specifies. Considering the scarcity of collections of weights incorporating contemporaneous specimens from a single, homogeneous site, this approach would appear to have a somewhat limited practical value. Nevertheless, given the required conditions, in addition to indicating the most commonly used norm, a most important aspect of Hemmy’s statistical approach is that it also identifies the various mass standards incorporated in a population of weights through an unbiased, objective approach.

It seems clear that the material evidence alone does not permit the identification of a single norm for ancient Mesopotamia. In all likelihood, a single mass standard that persisted unaltered over several millennia probably never existed for all of Mesopotamia. Powell suggests that, rather, the origin of the system of mass should be sought in subdivisions of the average load (Powell 1979: 87) that could be carried. This load was about 30 kg, or about a talent, for a person, and twice that for a pack animal, but its absolute mass probably varied somewhat from region to region, and probably also over time. At some point in antiquity, when simply reckoning the mass of loads no longer sufficed and a more accurate estimate was needed by weighing with balances, regional traditions and practices must have dictated or influenced significantly the precise value of the local unit of mass. Consequently, the fluctuation of the Mesopotamian mina by roughly 30 g on either side of the Babylonian mina of 504 g can be explained most convincingly by the possibility that all of these norms originated in a “cultural milieu” that recognized a “load” of about 28 to 31 kg.

Ancient metrology provides other corroborating evidence for the phenomenon that measures originate from practical considerations such as those based on
proportions of the human body, i.e., the use of one’s fingers, hand, and arm to describe lengths; foot and pace to quantify distance; and, so on. Because these factors are common to all and do not vary significantly from one population to another, there will invariably be an overlap of standards. Thus, the presence of a certain mass standard in several disparate regions implies that such measures were envisioned by humans who share body parts of approximately the same size, and who also could carry roughly the same amount of weight. Such overlaps of standards, therefore, do not necessarily support the notion of the spread of mass standards by diffusion, a hypothesis so popular with comparative metrologists.

*The Egyptian* Qedet. As with the Mesopotamian mina, the quest for the absolute mass of the *qedet* began somewhat later in the history of ancient metrology, with the publication in the mid-nineteenth century of balance weights from Egypt. In 1861, Chabas (1861: 15) published a single “domed” (dome-top) stone weight specimen of 45.3586 g inscribed as a five-*qedet* piece, which he divided by five to obtain 9.0717 g for the value of the *qedet*. Lepsius (cited in Petruso 1992: 5) proclaimed the *qedet* to be heavier than that calculated by Chabas, and without presenting his evidence published the value of the *qedet* to five decimal places, at 9.09591 g. The use of four or five decimal places seems excessive, and it was von Bergmann (1872: 165-69) who first attempted to distinguish between precision and accuracy in analyzing ancient Egyptian standards of mass. He selected four balance weights that ranged in mass from ca. 9.1 g to 9.47 g to propose for the *qedet* a mass value within this range. In doing so, he hinted at the meaninglessness of weighing ancient balance weights to five decimal places. Finally, Oscar Viedebantt (1923) asserted that ancient and primitive metrical standards must be expressed as ranges of values, rather than as single isolated values. This range constitutes an upper and lower limit for each metrical standard, between which—if the sample of the balance weights is sufficiently large—a clustering of specimens around a mean value might be expected to occur. This approach, as pointed out by Petruso (1992: 5), is the most logical and
useful principle to adopt when trying to comprehend ancient measurements and is used in our study of the weight assemblages from the Bronze Age shipwrecks.

With the publications of his major works (1864, 1882, 1898), Friedrich Hultsch became another acknowledged expert in the field of ancient metrology. His mathematical solutions to problems regarding the interrelationships among various ancient Mediterranean standards of mass was involved and, on the whole, unconvincing. Hultsch accepted the absolute mass proposed by Lepsius for the * qedet* and rounded it off to 9.096 g (1882: 373, n. 1), thereby perpetuating its use and acceptance by later students of ancient metrology (e.g., Lehmann-Haupt: 1918). Hence, by the end of the nineteenth century, two absolute mass values for the * qedet* were in use, that perpetuated by Hultsch, and that calculated by Chabas.

The first truly systematic analysis of the corpus of ancient Egyptian balance weights was published by Sir William Flinders Petrie (1926). Petrie's half century of field experience compelled him to address the more empirical aspects of ancient metrology. In a field that had been confused by comparative metrology, Petrie dealt exclusively with the material evidence. Unlike the comparative metrologists, who were engaged mostly in tracing the origins of modern standards of mass to a single absolute value that would be common to any mass standard, Petrie believed in the presence of multiple norms pertinent to each civilization. He also subscribed to the theory of "ranges of values," and broadened von Bergmann's mass range for the * qedet* of the Middle Kingdom to between 9.14 g and 9.59 g, with a peak at ca. 9.4 g (Petrie 1926: 13-15, confirmed by Hemmy 1937: 55; Petruso 1992: 16). As brilliant as Petrie was in his methodology, however, many of his theoretical conclusions are untrustworthy, particularly in the case of his attributions of non-Egyptian weights and his convoluted metrical derivations from nature (Petruso 1992: 6). Nevertheless, Petrie's contributions to metrology marked something of a turning point. His publications simply illustrate the differences between what he referred to as speculative (i.e., comparative) and empirical approaches, and his application of an analytical
methodology to the material and his compilation of an immense metrological database inspired similar empirical studies elsewhere. The stage was set for the advent of modern statistical methods in ancient metrology, such as the first successful attempt at it by Hemmy (1935; 1937) already cited above.
CHAPTER III
THE ULUBURUN BALANCE WEIGHTS

Preliminary Remarks

The Institute of Nautical Archaeology's (INA) shipwreck excavation between 1984 and 1994 at Uluburun, near Kaş in southern Turkey, brought to light one of the wealthiest and largest known assemblages of Bronze Age trade items found in the Mediterranean (Bass 1986; 1991; Bass, Pulak, Collon and Weinstein 1989; Pulak 1988, 1990a; 1990b; 1992, 1993, 1995). The shipwreck lay on a steep rocky slope at a depth of 44 to 52 m, with artifacts scattered down to 61 m. Built of cedar planks and frames in the ancient shell-first tradition, with pegged mortise-and-tenon joints securing its planks to each other and to the keel plank, it was about 15 to 16 m long (Bass 1989).

The ship's cargo, perhaps a royal one, comprised mostly raw materials, but manufactured goods were also present. The main cargo was 10 tons of primarily Cypriot copper in the form of 354 flat, usually four-handled rectangular ingots, and about 120 discoid "bun" ingots. Along with the four-handled ingots were similar forms with only two handles, which seem to disprove the early notion that the four-handled ingots were cast in imitation of dried ox hides. Also on board was a ton of tin ingots in both four-handled and bun shapes, the earliest known securely dated tin ingots, which when alloyed with the copper would have produced 11 tons of bronze.

Approximately one ton of terebinth resin (Mills and White 1989), carried in most of the 145 Canaanite jars recovered from the site, may be what the Egyptians termed smtr, a commodity sometimes transported in Canaanite jars from the Near East to the pharaoh for use as incense. The earliest known intact ingots of glass, some 175 of discoid shape in cobalt blue, turquoise, and in one instance, lavender, are likely the mekku and ehlpakku mentioned in tablets from Ras Shamra/Ugarit and Amarna as items traded from the Syro-Palestinian coast. Also carried on board were logs of
Egyptian ebony (*Dalbergia melanoxylon*); ostrich eggshells (probably intended for use as containers); ivory in the form of whole and sectioned elephant tusks, and more than a dozen hippopotamus teeth; opercula from murex seashells (a possible ingredient for incense); and modified tortoise carapaces (almost certainly sound-boxes for stringed musical instruments).

The largest group of manufactured goods on the ship consists of about 135 pieces of Cypriot ceramics, at least 80 of which are finewares (Base-ring II, White Slip II, White Shaved, Bucchero ware, and oil lamps). Among the Cypriot coarsewares were nine large storage jars (at least two of which contained Cypriot finewares, one pomegranates, and another probably olive oil), wall brackets, bowls, and trefoil-mouth pitchers. Five faience drinking cups were crafted as the heads of rams and, in one case, a woman. Poorly preserved bronze and copper caldrons and bowls suggest these must have also been a sizeable component of the manufactured part of the cargo.

Canaanite jewelry pieces include silver bracelets (and/or anklets) and gold pendants, one with a relief of a nude goddess holding a gazelle in each hand. A gold goblet or chalice, on the other hand, is of uncertain origin. Scrap gold and silver was also found in some quantity, with Egyptian objects of gold, electrum, silver, and stone among them, including a unique scarab inscribed with the cartouche of queen Nefertiti. Thousands of beads are of glass, agate, carnelian, quartz, faience, ostrich eggshell, seashell, and amber. Other artifacts include two duck-shaped ivory cosmetic containers, a trumpet carved from a hippopotamus tooth into the shape of a ram's horn, and more tin vessels (at least five) than had previously been found throughout the Bronze Age Mediterranean. Bronze tools comprise awls, drills and drill bits, chisels axes, adzes, and a saw. Also found were bronze spearheads, arrowheads, daggers, swords, and several stone maceheads, some of which must have been for the protection of the ship and its crew, while others must have been the personal possessions of the passengers on board. Foodstuffs, whether cargo or for shipboard use, included almonds, pine nuts, figs, olives, grapes, pomegranates, black cumin
(nigella), sumac, coriander, and wheat and barley (Haldane 1990, 1993). The wheat and barley were probably ground into flour for bread on the stone grinding trays and mortar carried aboard. Lead net and line sinkers, netting needles for repairing nets, fishhooks, and a bronze trident are evidence of fishing from the ship.

The presence of at least two Mycenaeans on the ship is indicated by a pair of steatite lentoid seals, a pair of swords, two types of glass relief beads almost certainly from two separate necklaces or pectorals, spearheads, curved knives, razors, chisels, amber beads of Mycenaean types, and nearly two dozen pieces of fine and utilitarian pottery. A bronze pin, at least five spearheads, and a stone ceremonial scepter-axe/mace head, with its closest parallel (albeit of bronze) found in Rumania, suggest connections between the ship or those aboard and lands to the north of Greece.

Perhaps the ship’s lading, along with information about its home port and destination, were included in two wooden diptychs, one of boxwood (Warnock and Pendleton 1991) with ivory hinges. Each diptych consisted of two wooden leaves slightly recessed and scored with crosshatching to receive wax writing surfaces (now lost) (Payton 1991). These tablets represent by far the earliest examples of their type.

Dendrochronological dating of a small piece of presumably fresh-cut firewood suggests a date of 1318 ± 2 B.C.E., or sometime shortly thereafter, for the sinking of the ship. The home port of the ship is difficult to ascertain. The Syrian, Kassite, and Assyrian/Old Babylonian cylinder seals found on the ship do not necessarily represent the nationality of the merchants aboard, as such seals were sent as tribute or gifts from Near Eastern rulers to both Egyptian and Aegean rulers. Although most of the cargo is of Cypriot and Syro-Palestinian origin, a cargo does not identify the nationality of the ship that carried it. Better evidence comes from the ship’s 24 stone anchors, which are of a type commonly used on Cyprus and along the coast of Syria-Palestine, but are virtually unknown in the Aegean. A Canaanite or Cypriot origin for the Uluburun ship is further suggested by tools, a razor, amulets, and other personal effects of those on board. A bronze female figurine, partly clad in gold, is similar to those of Syro-
Palestinian origin and may have served as the ship’s protective deity. Among the galley wares are saucer-shaped Syro-Palestinian oil lamps with charred nozzles, suggesting that they were used on the ship, while those of Cypriot origin are in pristine condition.

The ship also yielded 149 balance weights, which represents one of the most complete ancient weight assemblages to have come from the eastern Mediterranean. Among them are a group of some 19 weights shaped like various animals (zoomorphic forms). They are exceptional not only in their sheer number, but also because they include animal shapes not found anywhere else. While other much more extensive assemblages of weights have been recovered from Near Eastern sites, such as the more than 600 weights found during the excavations at Ras Shamra/Ugarit, the masses of 566 of which are known (Courtois 1990: 119), the Uluburun balance weights are unique in that they constitute the single largest collection of contemporaneous balance weights that were in use at the time of their loss. Additionally, two pairs of nested balance pans (one pair still in its partly preserved wooden container) recovered from the site indicate that there were at least two sets of scales carried on board. It is this assemblage, along with the smaller one found on the Cape Gelidonya shipwreck, that will be fully presented and examined in detail here.

The 149 balance weights recovered from the site represent several different sets, each complete or nearly complete with their specific denominations. The assemblage is nearly two and a half times larger than a similar collection of weights recovered from the Late Bronze Age shipwreck at Cape Gelidonya, in southern Turkey, which is also presented and reexamined in this study. The two shipwrecks, separated in time by about a century, have together yielded more than 210 weight pieces. All of the material addressed here has been recovered from the closed and undisturbed contexts of these two shipwreck sites and, as such, does not allow for the possibility of intrusive weight specimens. As was the case with the other artifacts found at Uluburun, special attention was given to the recovery of these weights to
avoid damage. Moreover, they have been carefully conserved and examined to maximize chances of deriving the metrical system or systems on which they were based.

With the exception of several hematite sphendonoid weights and eight zoomorphic weights published with their tentative mass values in the preliminary articles on the Uluburun shipwreck (Bass 1986: 292, ill. 31; Pulak 1988: 30-32, fig. 37-39a; Bass, Pulak, Collon, Weinstein 1989: 8-9, fig. 14), no Uluburun balance weights have been published. In fact, the cleaning and conservation of most pieces has only recently been completed. The complete catalog of Uluburun weights is given in Appendix C.

Of the 149 balance weights found on the Uluburun shipwreck, only 90 specimens, or 60.4%, can help us determine accurately the various standards and denominations represented aboard the ship. Nevertheless, this is still a significant number to work with and it will allow, for the most part, confident ascertainment of the weighing systems used, their relative importance, the nature of exchange and convertibility between the systems, and the number of denominations in each standard.

The itemization of 59 under- and overweight balance weights from Uluburun is as follows. Nineteen sphendonoid weights of bronze, of which four were fitted with lead plugs, and five hematite weights also with lead plugs, are mostly intact and retain their original shapes, but are most likely to be overweight because of the corrosion of the bronze and/or partial loss of the lead plugs. Two hematite weights have metal suspension loops. Of these, W 46 (KW 5143) is underweight because of the damage to its bronze loop, and W 107 (KW 2001) is most likely overweight due to the encrustation covering its fragile tin loop. Many of the 19 bronze weights in various animal shapes also have been altered severely by corrosion. The seven that contain a lead core seem to have suffered the most because of the damage done to the weight’s bronze exterior by the lead, which expanded during corrosion. Also excluded from the group of usable weights are eight lead weight specimens. Only six of the stone
balance weights from the entire Uluburun assemblage, therefore, are incomplete or have suffered extensive breakage, the type of damage almost certainly caused by impact experienced during the sinking of the ship.

The great majority of the Uluburun weights are hematite (or related iron ore) specimens, some of which have been meticulously shaped and carefully polished, but a few seem to be stone chunks worked only enough to produce irregular surfaces or facets. The 78 weights of hematite or related ores constitute just over 52% of all the weight pieces recovered from the site. These weights include the better and most durable pieces from the wreck and some of the smallest denominations as well. The smaller denominations were undoubtedly used especially to weigh rare and expensive materials such as gold, silver, precious stones, and probably spices, among other valuables. To these weights we may add the five hematite weights with lead plugs (W 36 [KW 2336], W 40 [KW 227], W 49 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]), which represent only 3.4% of the weights. These plugs allowed for the finer adjustment of the individual weight pieces to the desired mass values. Weights made of stones such as diorite or the softer steatite (or chlorite) and limestone, numbering 25 pieces and constituting 16.8% of the assemblage, were not fitted with lead plugs.

It is of interest to note that most of the smaller and fractional denominations are of the sphendonoid shape, as are all the pieces fitted with lead plugs. Moreover, the largest denomination among the sphendonoids is 10 units, while that among the domed examples is 100 units. All of this clearly indicates that the sphendonoid weights were more finely crafted and calibrated, and probably used only for the mensuration of small quantities of presumably precious goods, while the domed pieces were reserved for more bulky, and therefore, less valuable merchandise.

In addition to the stone weights on the Uluburun ship, there were a considerable number of metal balance weights. We have 38 bronze weights, 19 of which take the shape of various animals. Nine of these zoomorphic weights, many of which are finely crafted miniature masterpieces of naturalistic composition, have lead
cores. Four other bronze weights, all sphendonoids, are fitted with lead plugs. Eight lead weights of several shapes complete the Uluburun assemblage. Some of the lead pieces may, in fact, not be weights, while others appear to represent a standard not normally used in the Near East but seen commonly in the Aegean.

The corpus of Uluburun balance weights may be divided into four major morphological groupings, irrespective of material. Two are of the typical balance-weight shapes found during the Bronze Age: the sphendonoid and the domed. Each comprises balance weights crafted mostly from hematite or related iron-bearing minerals, but other types of stone, and bronze, are also used. A third group comprises only metal weights cast in the likeness of various animals, many with leaden cores. The final group, if truly a separate group, includes a few disk-shaped lead pieces that are similar to a category of weights known primarily from the Late Bronze Age Aegean region.

The stone weights were probably manufactured by a meticulous process of grinding until the desired form was achieved, after which a flat surface that was to serve as the weight's base was ground down further until the correct mass of the piece was achieved. Some of the weight specimens are much more carefully manufactured than the others. Conversely, a few appear to be odd bits of hematite minimally shaped or with only on one side flattened as a base and otherwise used as found.

All of the bronze balance weights seem to have been cast by the lost-wax method. Sometimes the mass of a piece required adjustment to the desired value, so molten lead was poured into a cavity provided in the base. This adjustment technique is also evident on some of the hematite weights; part of the base of the piece was drilled out and then filled with lead. While this practice is understandable when bronze weights are involved, as it is quite difficult to cast a metal weight to a precise mass, its application to stone weights, which could have been slowly and carefully ground down until the desired mass was achieved, is not quite clear. It seems possible also that such weights could have been recalibrated in this way to follow shifts in the mass norm.
This explanation seems attractive, but it is not fully convincing because a change in the mass of a norm would have involved adjustment of all weight pieces, not just five. Counterweighing weight pieces damaged during everyday use also seems likely, but the five Uluburun sphendonoids fitted with lead plugs are among the best-preserved specimens in the assemblage. It seems, therefore, that uniformity or regularity of size and shape was the priority, and that some pieces were underweight by the time these were achieved and therefore later adjusted to the desired mass by the addition of lead. It is of interest to note that none of the hematite sphendonoid weights from the Late Bronze Age Cape Gelidonya shipwreck were provided with lead plugs.

The zoomorphic balance weights were cast by the lost-wax process. Most of the smaller pieces are solid bronze, while the larger pieces were cast hollow and filled with lead, even though this by no means appears to be a general rule. While the solid bronze balance weights are largely well preserved in shape, nearly all of the zoomorphic weight pieces with a lead core have been badly damaged by the expansion of lead. In a few cases, this damage is limited to only large cracks and deformation of the shape of the balance weight, but in others it has caused considerable or total surface deterioration, exfoliation, and even loss of large portions of the weight piece itself.

The lead objects, tentatively described as weights, also have suffered some loss of mass through corrosion. This damage ranges from minimal on some specimens to extreme in one instance. Most of the lead disks appear to have been cast in some sort of mold and show no discernable evidence of subsequent working that is observed on many Aegean examples, whereby the molten lead was poured onto a flat or slightly concave surface in the quantity approximating as closely as possible the intended final mass, and then folded and formed into the desired shape (Michailidou 1990: 409-11). A certain amount of adjustment must have been made to the mass of every lead disk after it had cooled. Those that were underweight might have been dropped back into the crucible for repouring, while those determined to be overweight could have been
filed, shaved, or chiseled down to the appropriate final mass. Petruso (1992: 21) describes the manufacturing technique used to produce many of the Aegean weights: “Several of the disks seem to have received little if any treatment by the smith after pouring. The thicker disks, however, appear to have received much more attention by their manufacturers. In order to make them more compact and to consolidate them, their rims were folded back toward their centers, and then crimped and/or peened down. A disk so treated exhibits a rim perpendicular to its faces.” Petruso (1992: 21) notes further that the lead weights from Ayia Irini on Keos were not cast in molds, and comments that “to have done so would have been unnecessarily cumbersome, and, perhaps more to the point, would have afforded the makers no advantage in predicting the mass of the final product.” While this assessment may be true for the Aegean because of the almost exclusive use of a soft and malleable metal such as lead, it is by no means true for lead weights in general and for most of the specimens from Uluburun in particular. Moreover, numerous bronze sphendonoid and domed balance weights found at many sites in the ancient Near East, Egypt, and on Cyprus were cast almost exclusively in molds.

The Weight Assemblage

The excavation registration number (KW) and provenance of each weight piece are found in the catalog (Appendix C). The practical procedure of cataloging the weight pieces has consisted of carefully describing each weight specimen with regard to 1) type of material; 2) shape type; 3) dimensions of the weight and of any special features or details; 4) the mass of the object (expressed to one-hundredth of a gram in pieces less than 800 g, to one-tenth of a gram in pieces heavier than 800 g and less than 2000 g, and to within two grams for those heavier than 2000 g), with an estimate of the original mass if any loss has occurred; 5) extent of preservation and condition of the specimen; 6) detailed description of shape and base; 7) evaluation of quality of form and finish; 8) any special or peculiar features or details, including
marks to denote unit of mass, etc. The catalog entries, denoted as W 1, W 2, W 3, etc., are arranged in ascending order of mass. The Bodrum Museum of Underwater Archaeology inventory number, when present, also is cited and prefaced by “Museum Inv. No,” and the Uluburun field inventory number for each specimen is prefaced by the letters KW, for Kaş Wreck, and by “Lot” in a few instances, because such pieces were not assigned a KW number. The locus of each weight is indicated by two sets of letter-number combinations. The first designates the 1-meter grid square from which the weight piece was recovered, the second to a 25-centimeter square within the 1-meter square. Each grid square was subdivided into 50-centimeter squares specified as left (L) or right (R) quadrants on the upper half (U) of the grid square (UL or UR), or the lower half (L) of the grid square (LL or LR), and further divided into 25-centimeter quadrants numbered from 1 to 4 from left to right, starting at the upper left. A locus designated as O17 LR1, for example, gives the location of a balance weight piece as the 1-meter grid square O17, in the 50-centimeter quadrant at its lower right (LR), and within the 25-centimeter quadrant at the upper left (1) of LR. On the original working plans of the wreck, however, nearly every piece is precisely triangulated from fixed datum points on the site and recorded usually within a 2-cm margin of error. All dimensions are given in centimeters (cm), masses in grams (g). A minus sign (-) following a citation of mass indicates that the piece is damaged and obviously underweight; a plus sign (+) indicates that the piece has taken on a surface concretion and is therefore overweight. Restoration of the original masses of damaged weight pieces have been obtained by first restoring the weight’s form with plasticine and then taking its weight in water with a hydraulic balance. To obtain each piece’s original mass, the calculated volume is then multiplied by the specific gravity calculated for each weight piece. The methodology is detailed in Appendix B. The extreme care with which these procedures have been performed has resulted in the very close approximation of a weight’s mass before damage. Calculated masses thus obtained are indicated by the abbreviation (cal.). A conservative value for the density
of bronze is used for bronze weights whose actual densities cannot be calculated due
to mass loss in the weight piece itself. Their estimated masses are followed by the
abbreviation (est.) (tables 3-5).

Table 3. The Uluburun balance weights.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field. No.</th>
<th>Type</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 1</td>
<td>KW 5136</td>
<td>Sphendond</td>
<td>Limestone</td>
<td>1.56 g</td>
<td>-</td>
</tr>
<tr>
<td>W 2</td>
<td>KW 1660</td>
<td>Sphendond</td>
<td>Hematite</td>
<td>1.78 g</td>
<td>-</td>
</tr>
<tr>
<td>W 3</td>
<td>KW 1596</td>
<td>Cylindrical</td>
<td>Steatite</td>
<td>2.07 g</td>
<td>-</td>
</tr>
<tr>
<td>W 4</td>
<td>KW 5719</td>
<td>Cuboid</td>
<td>Limonite/Goethite</td>
<td>2.96 g</td>
<td>-</td>
</tr>
<tr>
<td>W 5</td>
<td>KW 337</td>
<td>Sphendond</td>
<td>Bronze</td>
<td>2.71 g (-)</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.49 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 6</td>
<td>KW 3212</td>
<td>Sphendond</td>
<td>Hematite</td>
<td>3.59 g</td>
<td>-</td>
</tr>
<tr>
<td>W 7</td>
<td>KW 1223</td>
<td>Sphendond</td>
<td>Bronze</td>
<td>0.82 g (-)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.74 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 8</td>
<td>KW 2891</td>
<td>Sphendond</td>
<td>Bronze</td>
<td>2.27 g (-)</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.90 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 9</td>
<td>KW 4269</td>
<td>Barrel-shaped</td>
<td>Hematite</td>
<td>3.92 g</td>
<td>-</td>
</tr>
<tr>
<td>W 10</td>
<td>KW 1583</td>
<td>Sphendond</td>
<td>Limonite</td>
<td>4.01 g</td>
<td>-</td>
</tr>
<tr>
<td>W 11</td>
<td>KW 3164</td>
<td>Sphendond</td>
<td>Hematite</td>
<td>4.01 g</td>
<td>-</td>
</tr>
<tr>
<td>W 12</td>
<td>KW 503</td>
<td>Sphendond</td>
<td>Bronze</td>
<td>3.21 g (-)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.07 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 13</td>
<td>KW 4466</td>
<td>Domed</td>
<td>Hematite</td>
<td>4.11 g</td>
<td>-</td>
</tr>
<tr>
<td>W 14</td>
<td>KW 228</td>
<td>Sphendond</td>
<td>Ilmenite</td>
<td>4.25 g</td>
<td>-</td>
</tr>
<tr>
<td>W 15</td>
<td>KW 2032</td>
<td>Rectangular</td>
<td>Hematite</td>
<td>4.39 g</td>
<td>-</td>
</tr>
<tr>
<td>W 16</td>
<td>Lot 918</td>
<td>Domed</td>
<td>Bronze</td>
<td>1.07 g (-)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.57 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 17</td>
<td>KW 955</td>
<td>Sphendond</td>
<td>Limonite</td>
<td>4.67 g</td>
<td>-</td>
</tr>
<tr>
<td>W 18</td>
<td>Lot 10968</td>
<td>Irregular</td>
<td>Hematite</td>
<td>4.79 g</td>
<td>-</td>
</tr>
<tr>
<td>W 19</td>
<td>KW 494</td>
<td>Sphendond</td>
<td>Hematite</td>
<td>5.38 g</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field. No.</th>
<th>Type</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 20</td>
<td>KW 1425</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>5.51 g</td>
<td></td>
</tr>
<tr>
<td>W 21</td>
<td>KW 4323</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>5.78 g (-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.89 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 22</td>
<td>KW 2899</td>
<td>Sphendonoid</td>
<td>Ilmenite (?)</td>
<td>5.97 g</td>
<td></td>
</tr>
<tr>
<td>W 23</td>
<td>KW 2784</td>
<td>Scarab</td>
<td>Hematite</td>
<td>6.04 g</td>
<td></td>
</tr>
<tr>
<td>W 24</td>
<td>Lot 1796</td>
<td>Sugar-loaf</td>
<td>Hematite</td>
<td>6.12 g</td>
<td></td>
</tr>
<tr>
<td>W 25</td>
<td>KW 467</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>4.82 g (-)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.23 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 26</td>
<td>KW 768</td>
<td>Domed (?)</td>
<td>Bronze</td>
<td>1.10 g (-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.31 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 27</td>
<td>KW 966</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>6.59 g</td>
<td></td>
</tr>
<tr>
<td>W 28</td>
<td>KW 4364</td>
<td>Domed</td>
<td>Hematite</td>
<td>6.62 g</td>
<td></td>
</tr>
<tr>
<td>W 29</td>
<td>KW 469</td>
<td>Sphendonoid</td>
<td>Diorite (?)</td>
<td>6.88 g</td>
<td></td>
</tr>
<tr>
<td>W 30</td>
<td>KW 4184</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>6.94 g</td>
<td></td>
</tr>
<tr>
<td>W 31</td>
<td>KW 1854</td>
<td>Sphendonoid</td>
<td>Diorite (?)</td>
<td>5.85 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.27 g (orig.)</td>
<td></td>
</tr>
<tr>
<td>W 32</td>
<td>KW 4424</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>5.63 g (-)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.47 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 33</td>
<td>KW 804</td>
<td>Trapezoïdal</td>
<td>Hematite</td>
<td>7.69 g</td>
<td></td>
</tr>
<tr>
<td>W 34</td>
<td>KW 2667</td>
<td>Sphendonoid</td>
<td>Limonite/Goethite</td>
<td>7.75 g</td>
<td></td>
</tr>
<tr>
<td>W 35</td>
<td>KW 1915</td>
<td>Sphendonoid</td>
<td>Diorite (?)</td>
<td>8.01 g</td>
<td></td>
</tr>
<tr>
<td>W 36</td>
<td>KW 2336</td>
<td>Sphendonoid</td>
<td>Hematite-Goethite/Limonite (?)/Lead</td>
<td>8.02 g (-)</td>
<td></td>
</tr>
<tr>
<td>W 37</td>
<td>KW 2377</td>
<td>Sphendonoid</td>
<td>Limonite</td>
<td>8.23 g</td>
<td></td>
</tr>
<tr>
<td>W 38</td>
<td>KW 4100</td>
<td>Domed</td>
<td>Stone</td>
<td>8.38 g</td>
<td></td>
</tr>
<tr>
<td>W 39</td>
<td>KW 3836</td>
<td>Discoid</td>
<td>Bronze</td>
<td>8.72 g (-)</td>
<td></td>
</tr>
<tr>
<td>W 40</td>
<td>KW 227</td>
<td>Sphendonoid</td>
<td>Ilmenite (?)/Lead</td>
<td>9.64 g (-)</td>
<td></td>
</tr>
<tr>
<td>Cat. No.</td>
<td>Field No.</td>
<td>Type</td>
<td>Material</td>
<td>Mass</td>
<td>Mark</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>----------------</td>
<td>---------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>W 41</td>
<td>KW 729</td>
<td>Loaf-shaped</td>
<td>Hematite</td>
<td>10.28 g</td>
<td>--</td>
</tr>
<tr>
<td>W 42</td>
<td>KW 731</td>
<td>Loaf-shaped</td>
<td>Kaolin or Argilite (?)</td>
<td>7.22 g (-)  10.29 g (cal.)</td>
<td>--</td>
</tr>
<tr>
<td>W 43</td>
<td>KW 787</td>
<td>Domed</td>
<td>Hematite</td>
<td>10.37 g</td>
<td>--</td>
</tr>
<tr>
<td>W 44</td>
<td>KW 5739</td>
<td>Irregular</td>
<td>Ilmenite</td>
<td>10.45 g</td>
<td>--</td>
</tr>
<tr>
<td>W 45</td>
<td>KW 3318</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>10.47 g</td>
<td>--</td>
</tr>
<tr>
<td>W 46</td>
<td>KW 5143</td>
<td>Sphendonoid</td>
<td>Ilmenite (?)/Bronze</td>
<td>10.61 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 47</td>
<td>KW 462</td>
<td>Sphendonoid</td>
<td>Limestone</td>
<td>10.68 g</td>
<td>--</td>
</tr>
<tr>
<td>W 48</td>
<td>KW 803</td>
<td>Loaf-shaped</td>
<td>Soapstone/Steatite</td>
<td>10.75 g</td>
<td>--</td>
</tr>
<tr>
<td>W 49</td>
<td>KW 5130</td>
<td>Domed</td>
<td>Limestone</td>
<td>10.89 g</td>
<td>--</td>
</tr>
<tr>
<td>W 50</td>
<td>KW 921</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>10.92 g</td>
<td>--</td>
</tr>
<tr>
<td>W 51</td>
<td>KW 4310</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>11.09 g</td>
<td>--</td>
</tr>
<tr>
<td>W 52</td>
<td>KW 5738</td>
<td>Loaf-shaped</td>
<td>Hematite</td>
<td>14.28 g</td>
<td>--</td>
</tr>
<tr>
<td>W 53</td>
<td>KW 3634</td>
<td>Loaf-shaped</td>
<td>Bronze</td>
<td>16.78 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 54</td>
<td>KW 3834</td>
<td>Domed</td>
<td>Ilmenite</td>
<td>18.70 g</td>
<td>--</td>
</tr>
<tr>
<td>W 55</td>
<td>KW 493</td>
<td>Loaf-shaped</td>
<td>Hematite</td>
<td>18.78 g</td>
<td>--</td>
</tr>
<tr>
<td>W 56</td>
<td>KW 1812</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>18.82 g</td>
<td>--</td>
</tr>
<tr>
<td>W 57</td>
<td>KW 2762</td>
<td>Domed</td>
<td>Limestone</td>
<td>18.70 g (-) 18.83 g (cal.)</td>
<td>--</td>
</tr>
<tr>
<td>W 58</td>
<td>KW 4546</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>18.83 g</td>
<td>--</td>
</tr>
<tr>
<td>W 59</td>
<td>KW 4272</td>
<td>Domed</td>
<td>Hematite</td>
<td>19.62 g</td>
<td>--</td>
</tr>
<tr>
<td>W 60</td>
<td>KW 788</td>
<td>Discoid</td>
<td>Lead</td>
<td>19.88 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 61</td>
<td>KW 323</td>
<td>Loaf-shaped</td>
<td>Hematite</td>
<td>22.02 g</td>
<td>--</td>
</tr>
<tr>
<td>W 62</td>
<td>KW 1771</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>18.69 g (-) 25.56 g (est.)</td>
<td>--</td>
</tr>
<tr>
<td>W 63</td>
<td>KW 4944</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>25.25 g (-) 25.96 g (cal.)</td>
<td>--</td>
</tr>
<tr>
<td>Cat. No.</td>
<td>Field. No.</td>
<td>Type</td>
<td>Material</td>
<td>Mass</td>
<td>Mark</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>W 64</td>
<td>KW 521</td>
<td>Domed</td>
<td>Limestone</td>
<td>27.28 g</td>
<td>--</td>
</tr>
<tr>
<td>W 65</td>
<td>KW 794</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>27.40 g</td>
<td>--</td>
</tr>
<tr>
<td>W 66</td>
<td>KW 4369</td>
<td>Domed</td>
<td>Limestone</td>
<td>27.90 g</td>
<td>--</td>
</tr>
<tr>
<td>W 67</td>
<td>KW 3972</td>
<td>Domed</td>
<td>Limestone</td>
<td>27.93 g</td>
<td>--</td>
</tr>
<tr>
<td>W 68</td>
<td>KW 1168</td>
<td>Domed</td>
<td>Lead</td>
<td>27.98 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 69</td>
<td>KW 3196</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>28.13 g</td>
<td>--</td>
</tr>
<tr>
<td>W 70</td>
<td>KW 3238</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>15.76 g (-)</td>
<td>28.30 g (est.)</td>
</tr>
<tr>
<td>W 71</td>
<td>KW 5751</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>28.75 g</td>
<td>--</td>
</tr>
<tr>
<td>W 72</td>
<td>Lot 2801</td>
<td>Trapezoidal</td>
<td>Hematite</td>
<td>28.86 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 73</td>
<td>KW 325</td>
<td>Discoid</td>
<td>Hematite</td>
<td>28.94 g</td>
<td>--</td>
</tr>
<tr>
<td>W 74</td>
<td>KW 3765</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>29.11 g</td>
<td>--</td>
</tr>
<tr>
<td>W 75</td>
<td>KW 492</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>22.41 g (-)</td>
<td>30.05 g (est.)</td>
</tr>
<tr>
<td>W 76</td>
<td>KW 4438</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>41.63 g</td>
<td>--</td>
</tr>
<tr>
<td>W 77</td>
<td>KW 4214</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>42.21 g</td>
<td>--</td>
</tr>
<tr>
<td>W 78</td>
<td>KW 564</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>37.83 g (-)</td>
<td>42.41 g (est.)</td>
</tr>
<tr>
<td>W 79</td>
<td>KW 487</td>
<td>Domed</td>
<td>Lead</td>
<td>42.62 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 80</td>
<td>KW 3047</td>
<td>Sphendonoid</td>
<td>Bronze</td>
<td>43.16 g (-)</td>
<td>43.66 g (est.)</td>
</tr>
<tr>
<td>W 81</td>
<td>KW 967</td>
<td>Prismatic</td>
<td>Hematite</td>
<td>45.62 g</td>
<td>--</td>
</tr>
<tr>
<td>W 82</td>
<td>KW 3467</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>45.65 g</td>
<td>--</td>
</tr>
<tr>
<td>W 83</td>
<td>KW 4125</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>45.82 g</td>
<td>--</td>
</tr>
<tr>
<td>W 84</td>
<td>KW 3839</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>45.84 g</td>
<td>--</td>
</tr>
<tr>
<td>W 85</td>
<td>KW 336</td>
<td>Sphendonoid</td>
<td>Diorite</td>
<td>46.24 g</td>
<td>--</td>
</tr>
<tr>
<td>W 86</td>
<td>KW 377</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>46.38 g (-)</td>
<td>46.61 g (cal.)</td>
</tr>
<tr>
<td>Cat. No.</td>
<td>Field No.</td>
<td>Type</td>
<td>Material</td>
<td>Mass</td>
<td>Mark</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>----------</td>
<td>------------------------</td>
<td>--------------</td>
<td>------</td>
</tr>
<tr>
<td>W 87</td>
<td>KW 4547</td>
<td>Domed</td>
<td>Diorite (?)</td>
<td>46.51 g</td>
<td>--</td>
</tr>
<tr>
<td>W 88</td>
<td>KW 4368</td>
<td>Domed</td>
<td>Hematite/Ilmenite (?)</td>
<td>46.79 g</td>
<td>--</td>
</tr>
<tr>
<td>W 89</td>
<td>KW 3801</td>
<td>Sphendonic</td>
<td>Ilmenite</td>
<td>47.02 g</td>
<td>--</td>
</tr>
<tr>
<td>W 90</td>
<td>KW 775</td>
<td>Sphendonic</td>
<td>Limonite/Goethite</td>
<td>47.31 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47.85 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 91</td>
<td>KW 4964</td>
<td>Sphendonic</td>
<td>Hematite</td>
<td>73.89 g</td>
<td>--</td>
</tr>
<tr>
<td>W 92</td>
<td>KW 874</td>
<td>Sphendonic</td>
<td>Bronze</td>
<td>76.04 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>82.09 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 93</td>
<td>KW 1171</td>
<td>Domed</td>
<td>Lead</td>
<td>85.49 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 94</td>
<td>KW 3232</td>
<td>Sphendonic</td>
<td>Hematite/Lead</td>
<td>87.12 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 95</td>
<td>KW 3978</td>
<td>Domed</td>
<td>Marl (?)</td>
<td>90.08 g</td>
<td>--</td>
</tr>
<tr>
<td>W 96</td>
<td>KW 174</td>
<td>Sphendonic</td>
<td>Steatite</td>
<td>90.30 g</td>
<td>¥</td>
</tr>
<tr>
<td>W 97</td>
<td>KW 5151</td>
<td>Domed</td>
<td>Magnetite</td>
<td>91.37 g</td>
<td>--</td>
</tr>
<tr>
<td>W 98</td>
<td>KW 863</td>
<td>Domed</td>
<td>Limonite</td>
<td>91.61 g</td>
<td>--</td>
</tr>
<tr>
<td>W 99</td>
<td>KW 1737</td>
<td>Sphendonic</td>
<td>Hematite</td>
<td>91.68 g</td>
<td>--</td>
</tr>
<tr>
<td>W 100</td>
<td>KW 3800</td>
<td>Sphendonic</td>
<td>Ilmenite</td>
<td>92.43 g</td>
<td>--</td>
</tr>
<tr>
<td>W 101</td>
<td>KW 5215</td>
<td>Sphendonic</td>
<td>Hematite/Lead</td>
<td>92.43 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 102</td>
<td>KW 3315</td>
<td>Sphendonic</td>
<td>Hematite</td>
<td>91.67 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>92.49 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 103</td>
<td>KW 935</td>
<td>Loaf-shaped</td>
<td>Ilmenite (?)</td>
<td>92.51 g</td>
<td>--</td>
</tr>
<tr>
<td>W 104</td>
<td>KW 3299</td>
<td>Sphendonic</td>
<td>Hematite/Lead</td>
<td>92.61 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 105</td>
<td>KW 153</td>
<td>Domed</td>
<td>Hematite</td>
<td>93.03 g</td>
<td>--</td>
</tr>
<tr>
<td>W 106</td>
<td>KW 774</td>
<td>Domed</td>
<td>Hematite</td>
<td>93.17 g</td>
<td>--</td>
</tr>
<tr>
<td>W 107</td>
<td>KW 2001</td>
<td>Sphendonic</td>
<td>Hematite/Tin</td>
<td>94.65 g (+)</td>
<td>--</td>
</tr>
<tr>
<td>W 108</td>
<td>KW 459</td>
<td>Discoid</td>
<td>Lead</td>
<td>139.51 g (-)</td>
<td>--</td>
</tr>
</tbody>
</table>
Table 3, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field. No.</th>
<th>Type</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 109</td>
<td>KW 298</td>
<td>Discoid</td>
<td>Lead</td>
<td>155.48 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 110</td>
<td>KW 3840</td>
<td>Domed</td>
<td>Bronze</td>
<td>160.49 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 111</td>
<td>KW 1979</td>
<td>Discoid</td>
<td>Lead</td>
<td>172.05 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 112</td>
<td>KW 1917</td>
<td>Domed</td>
<td>Diorite (?)</td>
<td>182.30 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>183.25 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 113</td>
<td>KW 2696</td>
<td>Domed</td>
<td>Hematite</td>
<td>184.33 g</td>
<td>--</td>
</tr>
<tr>
<td>W 114</td>
<td>KW 3233</td>
<td>Domed</td>
<td>Hematite</td>
<td>185.04 g</td>
<td>--</td>
</tr>
<tr>
<td>W 115</td>
<td>KW 5737</td>
<td>Domed</td>
<td>Hematite</td>
<td>183.83 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>185.24 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 116</td>
<td>KW 857</td>
<td>Domed</td>
<td>Hematite</td>
<td>185.64 g</td>
<td>--</td>
</tr>
<tr>
<td>W 117</td>
<td>KW 3279</td>
<td>Domed</td>
<td>Hematite</td>
<td>185.68 g</td>
<td>--</td>
</tr>
<tr>
<td>W 118</td>
<td>KW 3195</td>
<td>Domed</td>
<td>Hematite</td>
<td>186.74 g</td>
<td>--</td>
</tr>
<tr>
<td>W 119</td>
<td>KW 3343</td>
<td>Domed</td>
<td>Hematite</td>
<td>187.43 g</td>
<td>--</td>
</tr>
<tr>
<td>W 120</td>
<td>KW 3501</td>
<td>Domed</td>
<td>Diorite</td>
<td>275.79 g</td>
<td>L</td>
</tr>
<tr>
<td>W 121</td>
<td>KW 578</td>
<td>Domed</td>
<td>Hematite</td>
<td>278.61 g</td>
<td>--</td>
</tr>
<tr>
<td>W 122</td>
<td>KW 571</td>
<td>Domed</td>
<td>Serpentine</td>
<td>278.63 g</td>
<td>--</td>
</tr>
<tr>
<td>W 123</td>
<td>KW 3099</td>
<td>Domed</td>
<td>Limestone</td>
<td>323.57 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 124</td>
<td>KW 4165</td>
<td>Domed</td>
<td>Diorite</td>
<td>456.48 g</td>
<td>L</td>
</tr>
<tr>
<td>W 125</td>
<td>KW 710</td>
<td>Domed</td>
<td>Hematite</td>
<td>458.54 g</td>
<td>--</td>
</tr>
<tr>
<td>W 126</td>
<td>KW 382</td>
<td>Discoid</td>
<td>Diorite (?)</td>
<td>460.32 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>462.40 (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 127</td>
<td>KW 477</td>
<td>Domed</td>
<td>Hematite</td>
<td>916.7 g</td>
<td>--</td>
</tr>
<tr>
<td>W 128</td>
<td>KW 1511</td>
<td>Domed</td>
<td>Hematite</td>
<td>923.2 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>925.6 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 129</td>
<td>KW 849</td>
<td>Discoid</td>
<td>Lead/Bronze (?)</td>
<td>2,483 ± 2 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 130</td>
<td>KW 830</td>
<td>Sphendoid</td>
<td>Diorite (?)</td>
<td>7,632 ± 2 g</td>
<td>--</td>
</tr>
</tbody>
</table>
Table 4. The Uluburun zoomorphic weights.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Shape</th>
<th>Material</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 131</td>
<td>Lot 960</td>
<td>Duck</td>
<td>Bronze</td>
<td>1.46 g (-)</td>
</tr>
<tr>
<td>W 132</td>
<td>KW 5841</td>
<td>Calf (?)</td>
<td>Bronze/Lead</td>
<td>2.03 g (-)</td>
</tr>
<tr>
<td>W 133</td>
<td>KW 2128</td>
<td>Fly</td>
<td>Bronze</td>
<td>1.23 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.74 g (est.)</td>
</tr>
<tr>
<td>W 134</td>
<td>KW 873</td>
<td>Water fowl/</td>
<td>Bronze</td>
<td>1.94 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grebe (?)</td>
<td></td>
<td>5.48 g (est.)</td>
</tr>
<tr>
<td>W 135</td>
<td>KW 2736</td>
<td>Bull</td>
<td>Bronze</td>
<td>4.26 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.47 g (est.)</td>
</tr>
<tr>
<td>W 136</td>
<td>KW 237</td>
<td>Frog</td>
<td>Bronze</td>
<td>6.62 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.38 g (est.)</td>
</tr>
<tr>
<td>W 137</td>
<td>KW 4504</td>
<td>Bull</td>
<td>Bronze</td>
<td>5.22 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.55 g (est.)</td>
</tr>
<tr>
<td>W 138</td>
<td>KW 4119</td>
<td>Unidentified</td>
<td>Bronze/Lead</td>
<td>9.80 g (-)</td>
</tr>
<tr>
<td>W 139</td>
<td>KW 4943</td>
<td>Dog's head (?)</td>
<td>Bronze/Lead</td>
<td>10.28 g (-)</td>
</tr>
<tr>
<td>W 140</td>
<td>KW 3845</td>
<td>Unidentified</td>
<td>Lead</td>
<td>10.63 g (-)</td>
</tr>
<tr>
<td>W 141</td>
<td>KW 350</td>
<td>Duck</td>
<td>Bronze</td>
<td>8.33 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.21 g (est.)</td>
</tr>
<tr>
<td>W 142</td>
<td>KW 727</td>
<td>Calf</td>
<td>Bronze</td>
<td>3.26 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.29 g (est.)</td>
</tr>
<tr>
<td>W 143</td>
<td>KW 220</td>
<td>Frog</td>
<td>Bronze/Lead</td>
<td>19.52 g (-)</td>
</tr>
<tr>
<td>W 144</td>
<td>KW 335</td>
<td>Bull</td>
<td>Bronze</td>
<td>16.07 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20.00 g (est.)</td>
</tr>
<tr>
<td>W 145</td>
<td>KW 3081</td>
<td>Lioness</td>
<td>Bronze/Lead</td>
<td>26.77 g (-)</td>
</tr>
<tr>
<td>W 146</td>
<td>KW 2050</td>
<td>Bull</td>
<td>Bronze/Lead</td>
<td>54.97 g (-)</td>
</tr>
<tr>
<td>W 147</td>
<td>KW 468</td>
<td>Sphinx</td>
<td>Bronze</td>
<td>80.70 g (-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85.24 g (est.)</td>
</tr>
<tr>
<td>W 148</td>
<td>KW 3292</td>
<td>Lion</td>
<td>Bronze/Lead</td>
<td>171.45 g (-)</td>
</tr>
<tr>
<td>W 149</td>
<td>KW 582</td>
<td>Bucolic</td>
<td>Bronze/Lead</td>
<td>409.70 g (-)</td>
</tr>
</tbody>
</table>
Table 5. The Uluburun lead weights, as listed in table 3.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Type</th>
<th>Material</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 60</td>
<td>KW 788</td>
<td>Discoid</td>
<td>Lead</td>
<td>19.88 g (-)</td>
</tr>
<tr>
<td>W 68</td>
<td>KW 1168</td>
<td>Domed</td>
<td>Lead</td>
<td>27.98 g (-)</td>
</tr>
<tr>
<td>W 79</td>
<td>KW 487</td>
<td>Domed</td>
<td>Lead</td>
<td>42.62 g (-)</td>
</tr>
<tr>
<td>W 93</td>
<td>KW 1171</td>
<td>Domed</td>
<td>Lead</td>
<td>85.49 g (-)</td>
</tr>
<tr>
<td>W 108</td>
<td>KW 459</td>
<td>Discoid</td>
<td>Lead</td>
<td>139.51 g (-)</td>
</tr>
<tr>
<td>W 109</td>
<td>KW 298</td>
<td>Discoid</td>
<td>Lead</td>
<td>155.48 g (-)</td>
</tr>
<tr>
<td>W 111</td>
<td>KW 1979</td>
<td>Discoid</td>
<td>Lead</td>
<td>172.05 g (-)</td>
</tr>
<tr>
<td>W 129</td>
<td>KW 849</td>
<td>Discoid</td>
<td>Lead/Bronze (?)</td>
<td>2,483 ± 2 g (-)</td>
</tr>
</tbody>
</table>

Lists of weights in subsequent chapters conform to this general scheme.

Unless otherwise noted, all balance weights in this study were weighed with standard and electronic balances twice by the author, twice by different individuals on a new electronic balance, and finally three times by the author on an Ohaus Precision Plus, model TP4KD electronic laboratory balance with a capacity of 2,000 g at a sensitivity of ± 0.01 g up to 800 g, and a sensitivity of ±0.1 g from 801 g to 2,000 g. The masses of two particularly heavy specimens (K 129 [KW 849], W 130 [KW 830]), both in excess of 2,000 g, are accurate to only ±2 g. As noted earlier, a few of the Uluburun balance weights were previously weighed and published by George F. Bass and the present author, but the masses listed in the catalog presented here were taken in 1995 and 1996 and supersede all previously reported masses.

As for the typology of the Uluburun balance weights, aside from the zoomorphic and possibly the lead disk weights, the two major shapes are the sphendonoid and domed, with variants among them. There are several irregular weight pieces of seemingly haphazard shapes, and still others that are difficult to conveniently fit into any one major shape category. The Uluburun balance weights,
loosely grouped according to their shapes and denominations, the latter tentatively based on a standard unit mass of approximately 9.4 g (that not all weight pieces conform to this standard will be demonstrated below), may be summarized as follows:

-- For the fractional shekel weights (up to 9 g), 31 sphendonoids, 4 domed.
-- For the unit shekel weights, the predominant form is the sphendonoid, with 11 examples; 4 domed weights, 2 of which are under and 2 of which are over the mean value, probably also represent this unit.
-- For the 2-shekel weights, 4 sphendonoids 3 domed.
-- For the 3-shekel weights, 8 sphendonoids, 4 domed, and 1 disk.
-- For the 5-shekel weights, 1 sphendonoid, 2 domed.
-- For the 10-shekel weights, 8 sphendonoids, 5 domed.
-- For the 20-shekel weights, 8 domed. One other, underweight bronze domed weight probably corresponds to this unit.
-- For the 30-shekel weights, 3 domed.
-- For the 50-shekel (1 mina) weights, 3 domed, 1 disk-shaped weight; one badly damaged domed piece probably corresponds to this unit.
-- For the 100-shekel (double mina) weights, 2 domed.

Identification of the type of stone from which the weight pieces are crafted is important because it may be stated as a general principle that precision weights with a mass of 10 shekels or less are—at least from the Old Babylonian period—made of hematite (specific gravity: 5.2 - 5.3) and are generally in the form of sphendonoids, elongated barrels, or ducks (Powell 1973: 80). One cannot, however, assume that every stone resembling a duck, a barrel, or a sphendonoid incorporates an ancient standard of mass. In this study, pierced duck KW 4375, for example, has been excluded from the catalog because it is probably a bead or an amulet, but weights of irregular shapes have not been excluded because their function as weights is beyond any doubt. Powell (1979: 81) excludes barrels from his detailed study of
Mesopotamian weights on grounds that they may represent unfinished weight pieces or even unfinished cylinder seals. While this precaution may be necessary when analyzing a large corpus of weights from a multitude of ancient sites that are dispersed in time and space, it is not necessary with regard to shipwreck material, as it would be unlikely that hematite weights were being crafted on an ancient ship under sail. All hematite pieces from Uluburun, therefore, regardless of form and the quality of finish, have been taken to be useable balance weights.

Careful notation of the condition of the weight specimen is critical because it is on this basis that the specimen must be excluded from or included in the final statistical population from which norms or standards of mass are to be determined. A calculated estimate of the original mass is also necessary, as in most instances, it is possible to arrive at an accurate calculated value for the damaged specimen’s intended weight. This is especially important for unique pieces or for those crucial to the determination of a specific set’s denominations. The calculation of a weight’s original mass is possible in specimens with damaged areas that can be filled out with plasticine or some similar substance. By determining first the density of the stone and then the volume of the restored shape, one can arrive at a value that closely approximates its originally intended mass (see Appendix B). As this method requires additional equipment and is time consuming, it usually does not commend itself in most instances to the study of single or unprovenienced specimens, but it is invaluable for restoring elements of discrete assemblages or sets from which it would otherwise be impossible to obtain an adequate statistical sample. Where appropriate, this method of restoring a weight piece’s original mass has been employed in the present study. The mass of the object should be determined to the necessary degree of accuracy (usually ± 0.5 %) of the original mass, which greatly facilitates metrological analysis in the initial stages (Hemmy 1935: 83). It should be pointed out that the method cannot be used with composite weight pieces, where materials of different densities have been used. Restoration of a hematite weight originally fitted with a lead plug, for example, will
not yield accurate results, as the weight's calculated mass will be lower than its originally intended value.

Finally, the museum inventory number is needed, not only to provide other researchers with a means of controlling the material, but also to avoid duplication of data. In the Bodrum Museum of Underwater Archaeology, where both Uluburun and Cape Gelidonya shipwreck artifacts are stored, the identification and location of a specific object is sometimes possible only with use of the museum's inventory number. It is inevitable that different weights will occasionally have nearly identical descriptions, especially when smaller pieces are involved, but a mass value taken to 0.01 g and the weight's museum number provide each specimen with a unique identification (Powell 1979: 82).

All of this may seem rather obvious, but reviewing some published studies reveals quickly that the methodology is not at all obvious or standardized. Sometimes it is flawed as well, which partially or wholly invalidates the conclusions. While a statistical model based on quantal analysis has been taken as the basis for much of the work presented here, and having benefitted from guidelines presented in several excellent studies, the absence of established extensive statistical treatments of similar assemblages has made it necessary to proceed primarily by simple trial and error. First, in order to attribute weight pieces to specific denominations (in the virtual absence of unmarked pieces), it is necessary to have for the population an approximation of the mean norm, or standard unit mass, and some idea of the range of deviation from this mean. After intuitively suggesting a norm for the series, an approximate norm was indicated for each shipwreck assemblage by the results of quantal analysis. After the various quantal values were scrutinized, the most likely standards were ascertained and the weight pieces assigned to each standard. However, the mean norm was determined directly, first by averaging the resultant unit masses of the weight pieces, and then their weighted resultant unit masses, to arrive at a more realistic representation of the system's norm. This value was then taken as a
hypothesetical value for the assemblage's standard and was used to determine deviations for weights whose denominations could be attributed with certainty. When applicable, discovering the norm of a specific weight population through statistical means should yield a more reliable working value than an approach that assumes that a special purpose weight, such as an inscribed royal weight, represents a more precise and accurate denomination than do unmarked pieces. Hemmy (1935: 83-85) notes further that a weight's artistic finish and perfection of form are no criteria of its accuracy as representing a certain standard.

For example, having weighed over 2,000 weight specimens, which has shown that the range of deviation is much narrower for higher masses than for smaller ones, Powell (1979: 82) uses the mina norm derived from the bronze lion from Susa (mass 121,543 g) as the basis for evaluating the mass accuracy of all the weights he examined. He assumes this mina norm to represent a hypothetical norm that may be used to calculate the deviation for a group of weights whose denominations can be attributed with certainty. Using as an index the 506-g mina derived from the Susa lion weight, he calculates the deviation at the mina level to be 28 g for all specimens in his set, and 36 g for shekel fractions. The greater deviation of mass at the fractional level is the basis for his statement that higher units of mass exhibit a much narrower range of deviation, a property we know to be due to some degree to the technological deficiency of Bronze Age balances (Hemmy 1937: 40; Skinner 1967: 48-49). But, Powell’s assumption that the Susa lion provides the value closest to the originally intended mass of the Mesopotamian mina is suspect. First, the weight piece in question is of bronze, which, unlike hematite, is subject to corrosion and therefore may have taken on or lost some of its original mass. Second, while the Susa lion is a sanctioned weight, which makes it reasonable to assume the norm it represents is close to the original mass of the Mesopotamian mina, this is an assumption nevertheless. The reference weights to which the Susa lion weight was calibrated could have been slightly deficient or excessive in mass. This suspicion is, in fact, borne out in Powell’s
next step, in which he examines a control group of 59 specimens from Ischali (ancient Neribtum) and determines by statistical analysis a mean mina norm of 504 g with a deviation of ca. ± 15 (15.4) g for all specimens and ca. ± 16 (15.8) g for shekel fractions. He reasons that, because the weight specimens from Ischali almost all belong to the class of precision weights (i.e., hematite sphendonoids, barrels, and ducks), the range of deviation is therefore much smaller than that indicated by his preliminary analysis of the Susa lion. Powell also examines 20 specimens from Tell Asmar (ancient Eshnunna) and 31 from Kish. They yield a mean mina norm of 508 g for the Tell Asmar group, with a deviation of ca. ± 34 (33.6) g, and for those from Kish 506 ± ca. 25 (24.8) g, the mean deviation for these three groups being ± ca. 25 (24.6) g at the mina level. Powell (1979: 82) concludes, therefore, that in any large group of Mesopotamian weights that includes shekel fractions and multiples of the mina, one may expect an average deviation at the mina level of around ± 25 g, or about 5%. In a group of precision weights this deviation may be considerably smaller than ca. ± 25 g, but it is very unlikely to be smaller than ca. ± 15 g, whereas in groups of non-precision weights, the deviation will tend to be greater than ca. ± 25 g but will rarely exceed ca. ± 34 g. Given sufficient data (a minimum of 20 correctly attributed specimens roughly contemporaneous having the same provenance should be striven for), deviations that exceed ca. ± 34 g indicate the presence of disparate norms and the need for additional evidence and analysis. Deviations smaller than ca. ± 15 g indicate either a group of highly accurate precision weights or some mistake in methodology (Powell 1979: 83). Stated in other terms, Powell’s data indicate that even the Mesopotamian precision weights tolerated an inaccuracy of about 3% of the mass of the object being weighed, which accords well with the range of accuracy indicated for ancient balances (Hemmy 1937: 40; Skinner 1967: 6, 33, 48-49). In terms of the mina/shekel/barley corn norm of 504 g/8.4 g/0.05 g, this means for the shekel an inaccuracy of about 0.25 g. Although this amount does not appear to be significant, it does, in fact, represent about one day’s pay in silver, according to the wage scale in
the Code of Hammurabi, which ranges between 5 barley corns (0.23 g) and 6 barley corns (0.28 g) per day (Powell 1979: 83). In other words, deviations of more than ca. 5% above or below the designated mean norm will, in general, indicate either an insufficient statistical sample or the inclusions of incorrectly attributed specimens. This insightful information is most helpful and has been used extensively in this study to separate certain weights from one group and to include them in another.

**Distribution of the Weights on the Site**

To understand better the circumstances under which the Uluburun ship and its contents were scattered over the seabed, it will be worthwhile to inspect in some detail the distribution of artifacts and how it was affected by the seabed features of the site and the wreck-formation process. A thorough comprehension of the dynamics of artifact spillage will undoubtedly facilitate determination of the original locations of various artifacts on the ship and thereby allow the more accurate assignment of area functions on the ship. This in turn should aid to some extent our reconstruction of where the balance weights were stored on board and how they were grouped together.

The wreckage of the Uluburun ship was scattered over an area of approximately 13 x 28 m, with the shallowest recorded objects lying about 41 m deep and the deepest at nearly 61 m (fig. 1). Because of the considerable steepness of the rocky slope on which the ship came to rest, the gradient reaching over 35° in some places, much of the cargo and other objects were displaced through slipping or rolling downslope at different times as the ship’s hull gradually broke and disintegrated. In general terms, the ship’s keel was oriented west-east, following the slope of the seabed. Four rows of copper ingots, totaling some 10 tons, were positioned athwartships with a row of anchors, almost certainly spares, arranged in four pairs between the uppermost (highest on the slope) and second ingot rows. The part of the ship in which these stone anchors were stowed was probably the mast step area, near and probably slightly forward of midships.
Fig. 1. Site plan of the Uluburun shipwreck.
Due to the sharp incline on which the ship lay, many of the objects originally located at or near the stern—the end of the ship highest on the slope—spilled into deeper areas of the site. Moreover, because the ship originally settled on the rocky bottom with a list of about 15° to starboard, artifact displacement occurred not only downward along the slope’s gradient but also to starboard, in a southeasterly direction. This was true especially for the ship’s after half. Because the forward or bow portion of the hull had become wedged between the rock walls of the deep sand-filled gully in which it rested, much of the cargo there remained relatively intact even after the ship’s hull had disintegrated completely. Only some minor shifts occurred, particularly in the upper layers of the ingot rows, and some of the stone anchors there slid slightly down toward the deeper end of the gully. The part of the hull that lay upslope of the large rock outcrop at the center of the site and outside the gully apparently broke apart completely and spilled nearly all its cargo to starboard.

To facilitate comprehension of major artifact concentrations at Uluburun, the site has been divided into fairly discrete areas largely delineated by geophysical features, as determined by the excavator(s) who worked in each area. Starting with the shallowest part of the site, each area and its major artifact deposits is discussed below. All areas may be located on the site plan by their grid square coordinates.

The uppermost ledge on the site (L-O/10-13) is flanked by two sand gullies, one to its north (O-Q/10-13) and one to its south (L-K/9-13); each is separated from the ledge by a rocky ridge. Immediately downslope of this ledge was a row of copper ingots with their upslope ends protruding slightly above the ledge and their downslope ends resting against a row of stone anchors (L-P14). These ingots and anchors together had thus formed a barrier that prevented the downslope dispersal of artifacts from the ledge. As a result, this ledge area proved to be extremely rich in the variety and wealth of artifacts it harbored, especially jewelry and other small objects. The heavy blanket of encrustation over much of this ledge, however, required time-consuming, meticulous dissection of the rock-hard matrix with chisels and hammers.
One part of the ledge about 1.5 m square (L-M/10-11) was especially rich. After its
crust of corroded tin and other concretion had been removed, a small pocket of loose
sand yielded many artifacts, including bronze weapons and tools, gold, jewelry and
scrap gold and silver, cylinder seals, scarabs, beads of a variety of materials, lead net
sinkers, fish hooks, ceramic vessels, and copper and tin ingots, to name a few. This
deposit is also significant for the number (total = 37) of balance weights it yielded
(figs. 2, 3, 4): 10 sphendonoid weights: W 17 [KW 955], W 33 [KW 804], W 42 [KW
731], W 43 [KW 787], W 50 [KW 921], W 61 [KW 323], W 78 [KW 564], W 90
[KW 775], W 103 [KW 935], W 130 [KW 830]; 9 domed weights: W 24 [Lot 1796],
W 43 [KW 787], W 64 [KW 521], W 73 [KW 325], W 106 [KW 774], W 116 [KW
857], W 121 [KW 578], W 122 [KW 571], W 127 [KW 477]; 2 zoomorphic weights:
W 149 [KW 582]; 1 lead disk: W 129 [KW 849]), with 4 additional weights found
elsewhere on the ledge (sphendonoid pieces W 3 [KW 1596], W 35 [KW 1915], W 47
[KW 462], W 62 [KW 1771], and 2 domed pieces: W 98 [KW 863], W 128 [KW
1511]), some of which had been caught among the copper ingots. A few weight
pieces were also found around and under the stone anchors (4 sphendonoids: W 15
[KW 2032], W 20 [KW 1425], W 36 [KW 2336], W 86 [KW 377]; 2 domed: W 57
[KW 2762], W 113 [KW 2696]; 3 zoomorphic: W 133 [KW 2128], W 136 [KW 237],
W 143 [KW 220]). It seems, then, that the sets of weights were important or valuable
possessions worthy of being kept alongside some of the most precious objects carried
on the ship. As these weights were the highest-most on the slope, they are crucial to a
determination of the original weight stowage area(s) on the ship. They must have
been kept on board either precisely where they were found or, more likely, they spilled
down some distance from areas even farther up the slope corresponding to the very
stem of the ship. The only indication that at least some of the zoomorphic weights
were also stowed in the stern consists of perhaps the most spectacular of all Uluburun
weight specimens, and the heaviest among the zoomorphic pieces, W 149 (KW 582).
It is in fact noteworthy that all of the heaviest weight pieces on the wreck were found
<table>
<thead>
<tr>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>W33</td>
<td>W17</td>
<td>W130</td>
<td>W30</td>
</tr>
<tr>
<td></td>
<td>W61</td>
<td>W78</td>
<td>W42</td>
<td>W90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>W3</td>
<td>W62</td>
<td>W47</td>
<td></td>
<td>W35</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td>W86</td>
<td>W15</td>
<td>W36</td>
<td>W20</td>
</tr>
<tr>
<td></td>
<td>W8</td>
<td>W96</td>
<td>W10</td>
<td>W99</td>
<td>W2</td>
<td>W34</td>
</tr>
<tr>
<td></td>
<td>W12</td>
<td>W48</td>
<td>W77</td>
<td>W91</td>
<td>W89</td>
<td>W30</td>
</tr>
<tr>
<td>16</td>
<td>W9</td>
<td>W46</td>
<td>W70</td>
<td>W94</td>
<td>W69</td>
<td>W63</td>
</tr>
<tr>
<td></td>
<td>W44</td>
<td>W52</td>
<td>W5</td>
<td>W10</td>
<td>W21</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td>W31</td>
<td>W4</td>
<td>W63</td>
<td>W74</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td>W18</td>
<td>W11</td>
<td>W58</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>W107</td>
<td>W37</td>
<td>W82</td>
<td></td>
<td>W51</td>
</tr>
</tbody>
</table>

Fig. 2. Distribution of sphendonoid weights at Uluburun.
Fig. 3. Distribution of domed and lead weights at Uluburun.
Fig. 4. Distribution of zoomorphic weights at Uluburun.
in this area, an indication that even cumbersome pieces such as W 130 (KW 830), weighing some 7,632 ± 2 g, were probably kept with or near the other weights in the stern.

The gully bounding the heavily concreted ledge on the north (O-Q/10-13), almost totally devoid of artifacts in its upper reaches, revealed a heavy, disk-shaped weight piece (W 126 [KW 382]) that had undoubtedly been kept originally with the heavy weights that were recovered from the ledge area. This gully stretches downward along the sloping seabed until it reaches the large, boulder-like rock outcrop situated at the center of the site that forms the gully’s southern flank. Stone anchors and copper ingots covered the gully’s middle and lower reaches. That no additional weight pieces were found in these areas is a strong indication that nearly all the weights were kept fairly closely together at the stern, hence their dispersion directly down the slope. The southern gully (I-K/9-13) yielded important finds, among them elephant and hippopotamus ivory; gold jewelry; beads of faience, glass and amber; bronze weapons and tools; Mycenaean, Cypriot, and Canaanite pottery; and a large gold chalice. Several items in this area clearly indicated that this assemblage, along with some matching objects from the ledge area, originated higher up on the slope and is probably material that was stowed in the ship’s stern-most sections. That no weight pieces were found with these artifacts may be taken to mean either that the weights were stored forward of them, or that the bags or pouches that held the weights slipped a little downslope before they disintegrated and spilled their contents.

Farther downslope from the copper ingots, with the stone anchors marking its western reaches, is a seemingly flat, sandy plateau that abuts the large, boulder-like rock outcrop on its east side and the second row of copper ingots on its northeastern boundary. The northern sand gully fans out east and south to form the plateau’s northern perimeter while the southern sand gully merges with its southern side. The plateau slopes downward toward the south, with a sudden drop at about its midpoint that naturally divides it into two major sections: the northern (M-P/14-15) and the
southern (J-L/14-15). Because this plateau served as a large catchment for most of the artifacts originally located farther upslope, the greatest diversity and number of artifacts on the site were discovered here. The southern part yielded stirrup jars, tin vessels, bronze weapons and tools, ram’s-head drinking cups of faience, and many ceramic vessels. A great many balance weights (52 total) of all types were found here as well (32 sphendoid weights: W 2 [KW 1660], W 5 [KW 337], W 7 [KW 1223], W 8 [KW 2891], W 10 [KW 1583], W 12 [KW 503], W 14 [KW 228], W 19 [KW 494], W 22 [KW 2899], W 23 [KW 2784], W 25 [KW 467], W 27 [KW 966], W 29 [KW 469], W 34 [KW 2667], W 40 [KW 227], W 41 [KW 729], W 48 [KW 803], W 55 [KW 493], W 56 [KW 1812], W 65 [KW 794], W 75 [KW 492], W 76 [KW 4438], W 77 [KW 4214], W 81 [KW 967], W 85 [KW 336], W 86 [KW 377], W 89 [KW 3801], W 91 [KW 4964], W 92 [KW 874], W 96 [KW 174], W 99 [KW 1737], W 100 [KW 3800]; 11 domed weights: W 13 [KW 4466], W 16 [Lot 918], W 39 [KW 3836], W 54 [KW 3834], W 57 [KW 2762], W 66 [KW 4369], W 68 [KW 1168], W 88 [KW 4368], W 105 [KW 153], W 113 [KW 2696], W 125 [KW 710]; 9 zoomorphic weights: W 133 [KW 2128], W 134 [KW 873], W 135 [KW 2736], W 136 [KW 237], W 141 [KW 350], W 142 [KW 727], W 143 [KW 220], W 144 [KW 335], W 147 [KW 468]).

Immediately east of the northern extremity of the sand plateau and extending upslope along the north side of the large rock outcrop is a large gully (M-P/16-22). Here, between its steep rocky walls, the ship became lodged. At the upper end were located three rows of copper ingots, most of which still retained their original stacking patterns, and 16 stone anchors, along with many more bronze tools, weapons, beads, seals, glass ingots, ceramic and bronze vessels, ivory cosmetic containers, and many other finds. Many balance weights (51 total) had also been dispersed down into deeper areas through this funnel-like gully: 29 sphendoid weights: W 1 (KW 5136), W 4 (KW 5719), W 6 (KW 3212), W 9 (KW 4269), W 11 (KW 3164), W 21 (KW 4323), W 30 (KW 4184), W 32 (KW 4424), W 37 (KW 2377), W 44 (KW 5739), W
45 (KW 3318), W 46 (KW 5143), W 51 (KW 4310), W 52 (KW 5738), W 53 (KW 3634), W 58 (KW 4546), W 63 (KW 4944), W 69 (KW 3196), W 70 (KW 3238), W 71 (KW 5751), W 74 (KW 3765), W 80 (KW 3047), W 82 (KW 3467), W 83 (KW 4125), W 84 (KW 3839), W 94 (KW 3232), W 101 (KW 5215), W 102 (KW 3315), W 104 (KW 3299); 16 domed weights W 38 (KW 4100), W 49 (KW 5130), W 59 (KW 4272), W 67 (KW 3972), W 87 (W 4547), W 95 (KW 3978), W 97 (KW 5151), W 110 (KW 3840), W 114 (KW 3233), W 115 (KW 5737), W 117 (KW 3279), W 118 (KW 3195), W 119 (KW 3343), W 120 (KW 3501), W 123 (KW 3099), W 124 (KW 4165); and 6 zoomorphic weights W 132 (KW 5841), W 137 (KW 4504), W 139 (KW 4943), W 140 (KW 3845), W 145 (KW 3081), W 148 (KW 3292). This gully continues eastward and drops steeply into deeper water where more pottery, pithoi, and other scattered artifacts were recovered from depths of up to 61 m. The deepest weight pieces were found at about 48 m, in an area that corresponded approximately to the forward extremity of the ship.

Just downslope (east) of the boulder-like rock outcrop and south of the central part of the main gully lay a small deposit (K-L 19) comprising a few Canaanite amphorae, other pottery vessels, and hundreds of small fish-net weights. These artifacts must have rolled over the boulder while the hull was still relatively intact and dropped directly below and downslope of the boulder, where they were discovered. The two weight pieces found here, splenodonid weight W 107 (KW 2001) and zoomorphic weight W 146 (KW 2050), also must have made their way over the boulder.

The final area to be discussed is the sand gully that runs parallel to the main gully and forms the southern extent of the site (C-H/16-33). The lower reaches of the small gully to the south of the ledge and the south end of the plateau merge to form the western boundary of this gully. Artifacts slipping down the steep seabed appear to have been channeled by the plateau and the small southern gully into this area and were scattered over a wide area and into much deeper reaches of the site. There were
at least four large pithoi, some of which must have contained the Cypriot pottery found scattered over the slope. The spillage of artifacts, although decreasing in frequency, was followed down to about 60 m. Only one weight was found here, a domed piece (W 112 [KW 1917]) in grid square F21.

We have attempted to give a somewhat detailed account of how the weight pieces at Uluburun were distributed throughout the site. It is unfortunate that the sea bed on which the ship came to rest is so steep, causing the downward or downslope shift of almost all objects aboard the ship. This would have been especially true for the weight pieces, some of the smallest, densest, and most uniformly shaped objects on the ship. They could have very easily rolled downward and among other artifacts into virtually every part of the site. But by studying the seabed contours, the dispersion of other artifacts on the site, and the locus of each weight piece and how it may have come to rest there, we should be able to reconstruct with some confidence the original locations of some of the weights on the ship and how they may have been grouped together. For example, although weight pieces were found scattered over most of the site, it was clear from the onset that all three major groups of weights—sphendonoid, domed, and zoomorphic—were represented in the assemblage discovered high up on the slope, thereby revealing that in all likelihood most of the weight sets were kept at or very near the stern. This discovery is hardly surprising considering that several shipwrecks excavated in Turkey by INA, albeit of much later periods, have revealed that most of the weight pieces, scales, and steelyards were generally kept at the ship’s stern along with other valuables belonging to the ship’s captain, merchants, or passengers (Sams 1982: 202-30; Hocker 1993: 13-21). A similar observation was made for the Cape Gelidonya ship (see Chapter II).

More careful examination of the weight pieces from highest on the slope (L-M 10) shows that there were five sphendonoid weights (W 17 [KW 955], W 33 [KW 804], W 50 [KW 921], W 103 [KW 935], W 130 [KW 830]), but no domed or zoomorphic pieces, examples of which are instead found just slightly farther down the
slope in grid squares L-M 11. This seemingly minor point may in fact be a strong indication that at least some of the sphendonoid weight pieces were kept separate from the domed weights, but it would seem improbable that all of the domed weights had been segregated from, and therefore were stored slightly downslope of, or forward of the sphendonoid weights. A more likely explanation is that each group of weights was kept in its own bag, perhaps even beside one another. After the ship sank, the bags could have easily become separated from each other, if for example the bag of domed weights slid slightly down the slope. Of course it is also possible, although unlikely, that the different bags with their respective groups of weight pieces were originally stored on the ship exactly where they were found during the excavation.

**Metrological Analysis**

Of the 149 objects cataloged as balance weights or possible balance weights from the Uluburun shipwreck, 8 are damaged probably from impact experienced during the sinking of the ship and another 13, all of metal, are severely altered or deformed from corrosion such that the lost metal has rendered the pieces significantly underweight. Seventeen more metal balance weights, while seemingly undamaged and retaining their overall original shapes, no longer match closely their intended masses. Nineteen metal objects identified as zoomorphic weights also have suffered to varying degrees from corrosion and, hence, are underweight. This alteration of mass in metal weight pieces occurs mostly through oxidation, whereby oxygen and carbonic acid form a crust on the weight's surface and thus increase its mass. When this crust breaks away, exfoliates, or is removed, some of the weight's original surface usually adheres to it and mass is lost. A metal weight whose surface looks quite clear and smooth, for example, may actually have suffered much loss of surface during removal of this crust. But the most serious alteration of the mass of balance weights from shipwreck sites is the severe dissolution or leaching of metal that results from prolonged submersion in sea water. One weight piece from Uluburun has lost as much
as 75% of its original mass in this way. Therefore, stone and metal balance weights are treated discretely here, as stone is the sole material permitting accurate discrimination of mass (Petrie 1926: 3). For this reason, only intact stone weights are employed in our study of the Uluburun balance weight denominations. Yet even when stone weights are chipped, the original form can be closely approximated and the mass quite accurately reconstructed. Therefore many damaged weights have been restored and their calculated masses indicated, and I have also attempted, where possible, to attribute the metal weights from Uluburun to their respective denominations after estimating their loss of mass (see Appendix B). The remaining 92 balance weights from Uluburun constitute the population subjected to quantal searches, using Kendall’s statistic, that will aid in the determination of values that most likely represent the standard unit mass or masses on which the weights are based. Of course such values will be independent of all external evidence, subjective or objective.

Before embarking on a statistical path, however, it may prove helpful to approach the Uluburun weight assemblage through a more intuitive analysis and begin by examining the specimens for possible denominational marks. Unfortunately, only six bear markings of any sort. Three are stone balance weights (one sphendonoid and two domed) marked with simple incisions, while three bronze sphendonoids bear impressed marks that appear to have been made with a hammer and narrow-bladed chisel. While some of these marks are probably primary, that is, made immediately after the pieces were crafted, others may be secondary, and could confound our efforts to attribute them to a standard or norm. With the possible exception of the marks found on the three small bronze sphendonoid weights, no mark stands out as an obvious indicator of the denomination represented by the mass of the weight piece in question. It seems, therefore, that only 3 of the 83 sphendonoids from Uluburun bear marks that could indicate their units. Unfortunately, all three are bronze pieces of fractional denominations that have been rendered extremely underweight by corrosion. Balance weights W 5 (KW 337) of 2.71 g (3.49 g, est.) and W 8 (KW 2891) of 2.27 g
(3.90 g, est.) both bear on their top surfaces the mark "I," almost certainly stamped or made with a small chisel after they were cast. A third bronze weight, W 25 (KW 467) of 4.82 g (6.32 g, est.), is incised with a similar mark, "i," which does not include the short crossbars or horizontal incisions at either end of the long bar. It is impossible to determine with certainty the intended masses of these weight pieces. The meanings of the marks consequently elude us, but we may infer that, in relative terms, the mass of W 25 (KW 467) is very roughly twice that of the other two weights. If the mark "i" on W 25 (KW 467) denotes a single unit of a specific, if unknown, standard, then those marked with the "I" may represent half a unit of the same standard, the crossbars perhaps conveying the idea of a cut, partial, or half unit.

Because these bronze weight pieces cannot help us determine the standard unit mass they originally represented, they, along with the other metal weights, have been excluded from the population subjected to quantal searches. Nevertheless, these marked specimens deserve careful scrutiny. The two examples bearing the mark "I," specifically W 5 (KW 337) and W 8 (KW 2891), weigh 2.71 g (3.49 g, est.) and 2.27 g (3.90 g, est.), respectively. It is difficult to know with certainty the norms of these fractional weights, but if they are based on a shekel of ca. 9.4 g (the Ugaritic/Syrian shekel or the Egyptian qedet), then they probably correspond to 1/3-unit pieces. Weight W 25 (KW 467), the piece that displays the mark "i" and weighs 4.82 g, but probably originally weighed 6.23 g, may correspond to 2/3 of a shekel of ca. 9.4 g. Conversely, these three weight pieces may also represent two 1/2-unit pieces and a 1-unit piece of a standard of ca. 7.4 g.

Of the three marked stone balance weights, sphendonoid W 96 (KW 174) carries on both its base and top surface a mark in the shape of an arrow consisting of three converging lines of approximately equal length, although the mark on the top surface is barely discernible due to wear from excessive handling. This sign (V) is known in the Cypro-Minoan repertory (Masson 1971: 502, fig. 50.9), but is not recognized as corresponding to or representing a numerical denomination. With its
mass of 90.30 g it is somewhat less (ca. 3%) than a 10-unit piece of ca. 94 g, but this deviation is well within the acceptable range for that unit. The two remaining marked pieces, of domed shape (W 120 [KW 3501] and W 124 [KW 4165]), are crafted from diorite and weigh 275.79 g and 456.48 g, respectively. As such, they correspond to 30-units of 9.19 g each, and 50-units of 9.13 g each or a mina of 456.48 g, respectively. Incised on the base of each are two short, perpendicular lines that meet at one end but do not intersect, thus: "L." As the marks are similar, differing essentially in size only, it seems unlikely that they represent mass denominations. Perhaps they are owner’s marks, or even identification marks indicating that they are elements of a particular balance weight set. While the latter explanation seems favorable in light of the identical stone type from which the two pieces have been fashioned, other specimens made from the same stone, and so presumably elements of the same set, do not carry such marks.

This being the case, it would seem somewhat surprising that a merchant performing routine weighing operations did not benefit from using weights marked to indicate the denominations of their respective masses, having instead to commit each piece to memory in order to correctly and quickly weigh his merchandise. When the entire assemblage of balance weights is considered, this seems an even more formidable task. But, if we assume that the approximately 150 balance weights on the Uluburun ship actually represent seven or more different sets, each carried in its own leather bag, bag compartment, or pouch, and that each merchant owned just a few sets at most, then the job becomes somewhat more manageable. Furthermore, if one assumes that the elements making up a specific balance weight set are made essentially from the same material and to a certain shape, differing only in size, then weighing becomes even less problematic. The merchant simply needs to remember the limited number of pieces in his set and to know that each sequentially larger weight piece corresponds to the next larger unit or denomination. After some practice with such a set, weighing could become a simple matter.
In our attempt to intuitively assess the standard unit mass or masses represented among the assemblage of balance weights from Uluburun, only those pieces that almost certainly represent weight pieces are considered. Certain objects originally cataloged as weight pieces in the field have been eliminated from the main list either because of their dubious nature or they have since been identified as objects other than weight pieces, such that the catalog presented here comprises all objects currently recognized as weights and probably incorporates nearly all of the weights carried aboard the ship. It is certain that additions, deletions, and amendments will be made in the final publication phase, however, after all the artifacts from the site have been studied in detail.

Based on the standard unit mass of ca. 9.4 g tentatively proposed for the Uluburun weights, therefore, the individual weight pieces with their predicted unit attributions and respective resultant unit masses are given in table 6.

Table 6. The Uluburun weights and their predicted unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 1</td>
<td>KW 5136</td>
<td>1.56 g</td>
<td>--</td>
<td>1/6 (?)</td>
<td>9.36 g</td>
</tr>
<tr>
<td>W 2</td>
<td>KW 1660</td>
<td>1.78 g</td>
<td>--</td>
<td>1/5 (?)</td>
<td>8.9 g</td>
</tr>
<tr>
<td>W 3</td>
<td>KW 1596</td>
<td>2.07 g</td>
<td>--</td>
<td>1/4 (?)</td>
<td>8.28 g</td>
</tr>
<tr>
<td>W 4</td>
<td>KW 5719</td>
<td>2.96 g</td>
<td>--</td>
<td>1/3 (?)</td>
<td>8.88 g</td>
</tr>
<tr>
<td>W 5</td>
<td>KW 337</td>
<td>2.71 g (-) 3.49 g (est.)</td>
<td>I</td>
<td>1/2 (?)</td>
<td>6.98 g (est.) 10.47 g (est.)</td>
</tr>
<tr>
<td>W 6</td>
<td>KW 3212</td>
<td>3.59 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>7.18 g</td>
</tr>
<tr>
<td>W 7</td>
<td>KW 1223</td>
<td>0.82 g (-) 3.74 g (est.)</td>
<td>--</td>
<td>--</td>
<td>7.48 g (est.)</td>
</tr>
<tr>
<td>W 8</td>
<td>KW 2891</td>
<td>2.27 g (-) 3.90 g (est.)</td>
<td>I</td>
<td>1/2 (?)</td>
<td>7.8 g (est.) 11.70 g (est.)</td>
</tr>
<tr>
<td>W 9</td>
<td>KW 4269</td>
<td>3.92 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>7.84 g</td>
</tr>
</tbody>
</table>
Table 6, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 10</td>
<td>KW 1583</td>
<td>4.01 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.02 g</td>
</tr>
<tr>
<td>W 11</td>
<td>KW 3164</td>
<td>4.01 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.02 g</td>
</tr>
<tr>
<td>W 12</td>
<td>KW 303</td>
<td>3.21 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.07 g (est.)</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.14 g (est.)</td>
</tr>
<tr>
<td>W 13</td>
<td>KW 4466</td>
<td>4.11 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.22 g</td>
</tr>
<tr>
<td>W 14</td>
<td>KW 228</td>
<td>4.25 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.50 g</td>
</tr>
<tr>
<td>W 15</td>
<td>KW 2032</td>
<td>4.39 g</td>
<td>--</td>
<td>1/2 (?)</td>
<td>8.78 g</td>
</tr>
<tr>
<td>W 16</td>
<td>Lot 918</td>
<td>1.07 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.57 g (est.)</td>
<td>--</td>
<td>1/2 (?)</td>
<td>9.14 g (est.)</td>
</tr>
<tr>
<td>W 17</td>
<td>KW 955</td>
<td>4.67 g</td>
<td>--</td>
<td>1/2</td>
<td>9.34 g</td>
</tr>
<tr>
<td>W 18</td>
<td>Lot 10968</td>
<td>4.79 g</td>
<td>--</td>
<td>1/2</td>
<td>9.58 g</td>
</tr>
<tr>
<td>W 19</td>
<td>KW 494</td>
<td>5.38 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>8.07 g</td>
</tr>
<tr>
<td>W 20</td>
<td>KW 1425</td>
<td>5.51 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>8.27 g</td>
</tr>
<tr>
<td>W 21</td>
<td>KW 4323</td>
<td>5.78 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.89 g (est.)</td>
<td>--</td>
<td>2/3 (?)</td>
<td>8.84 g (est.)</td>
</tr>
<tr>
<td>W 22</td>
<td>KW 2899</td>
<td>5.97 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>8.96 g</td>
</tr>
<tr>
<td>W 23</td>
<td>KW 2784</td>
<td>6.04 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.06 g</td>
</tr>
<tr>
<td>W 24</td>
<td>Lot 1796</td>
<td>6.12 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.18 g</td>
</tr>
<tr>
<td>W 25</td>
<td>KW 467</td>
<td>4.82 g (-)</td>
<td>--</td>
<td>1</td>
<td>6.23 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.23 g (est.)</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.35 g (est.)</td>
</tr>
<tr>
<td>W 26</td>
<td>KW 768</td>
<td>1.10 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.31 g (est.)</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.47 g (est.)</td>
</tr>
<tr>
<td>W 27</td>
<td>KW 966</td>
<td>6.59 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.89 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4 (?)</td>
<td>8.79 g</td>
</tr>
<tr>
<td>W 28</td>
<td>KW 4364</td>
<td>6.62 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>9.93 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4 (?)</td>
<td>8.82 g</td>
</tr>
<tr>
<td>W 29</td>
<td>KW 469</td>
<td>6.88 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>10.32 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4 (?)</td>
<td>9.17 g</td>
</tr>
<tr>
<td>W 30</td>
<td>KW 4184</td>
<td>6.94 g</td>
<td>--</td>
<td>2/3 (?)</td>
<td>10.41 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4 (?)</td>
<td>9.25 g</td>
</tr>
<tr>
<td>Cat. No.</td>
<td>Field No.</td>
<td>Mass</td>
<td>Mark</td>
<td>Unit Attribution</td>
<td>Resultant Unit Mass</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>-----------------</td>
<td>------</td>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>W 31</td>
<td>KW 1854</td>
<td>5.85 g (-)</td>
<td>--</td>
<td>--</td>
<td>7.27 g (orig.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.27 g (orig.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 32</td>
<td>KW 4424</td>
<td>5.63 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.47 g (est.)</td>
<td></td>
<td></td>
<td>7.47 g (est.)</td>
</tr>
<tr>
<td>W 33</td>
<td>KW 804</td>
<td>7.69 g</td>
<td>--</td>
<td>1 (?)</td>
<td>7.69 g</td>
</tr>
<tr>
<td>W 34</td>
<td>KW 2667</td>
<td>7.75 g</td>
<td>--</td>
<td>1 (?)</td>
<td>7.75 g</td>
</tr>
<tr>
<td>W 35</td>
<td>KW 1915</td>
<td>8.01 g</td>
<td>--</td>
<td>1 (?)</td>
<td>8.01 g</td>
</tr>
<tr>
<td>W 36</td>
<td>KW 2336</td>
<td>8.02 g (-)</td>
<td>--</td>
<td>1 (?)</td>
<td>8.02 g (-)</td>
</tr>
<tr>
<td>W 37</td>
<td>KW 2377</td>
<td>8.23 g</td>
<td>--</td>
<td>1 (?)</td>
<td>8.23 g</td>
</tr>
<tr>
<td>W 38</td>
<td>KW 4100</td>
<td>8.38 g</td>
<td>--</td>
<td>1 (?)</td>
<td>8.38 g</td>
</tr>
<tr>
<td>W 39</td>
<td>KW 3836</td>
<td>8.72 g (-)</td>
<td>--</td>
<td>1</td>
<td>8.72 g (-)</td>
</tr>
<tr>
<td>W 40</td>
<td>KW 227</td>
<td>9.64 g (-)</td>
<td>--</td>
<td>1</td>
<td>9.64 g (-)</td>
</tr>
<tr>
<td>W 41</td>
<td>KW 729</td>
<td>10.28 g</td>
<td>--</td>
<td>1</td>
<td>10.28 g</td>
</tr>
<tr>
<td>W 42</td>
<td>KW 731</td>
<td>7.22 g (-)</td>
<td>--</td>
<td>--</td>
<td>10.29 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.22 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 43</td>
<td>KW 787</td>
<td>10.37 g</td>
<td>--</td>
<td>1</td>
<td>10.37 g</td>
</tr>
<tr>
<td>W 44</td>
<td>KW 5739</td>
<td>10.45 g</td>
<td>--</td>
<td>1</td>
<td>10.45 g</td>
</tr>
<tr>
<td>W 45</td>
<td>KW 3318</td>
<td>10.47 g</td>
<td>--</td>
<td>1</td>
<td>10.47 g</td>
</tr>
<tr>
<td>W 46</td>
<td>KW 5143</td>
<td>10.61 g (-)</td>
<td>--</td>
<td>1</td>
<td>10.61 g (-)</td>
</tr>
<tr>
<td>W 47</td>
<td>KW 462</td>
<td>10.68 g</td>
<td>--</td>
<td>1</td>
<td>10.68 g</td>
</tr>
<tr>
<td>W 48</td>
<td>KW 803</td>
<td>10.75 g</td>
<td>--</td>
<td>1</td>
<td>10.75 g</td>
</tr>
<tr>
<td>W 49</td>
<td>KW 5130</td>
<td>10.89 g</td>
<td>--</td>
<td>1</td>
<td>10.89 g</td>
</tr>
<tr>
<td>W 50</td>
<td>KW 921</td>
<td>10.92 g</td>
<td>--</td>
<td>1</td>
<td>10.92 g</td>
</tr>
<tr>
<td>W 51</td>
<td>KW 4310</td>
<td>11.09 g</td>
<td>--</td>
<td>1</td>
<td>11.09 g</td>
</tr>
<tr>
<td>W 52</td>
<td>KW 5738</td>
<td>14.28 g</td>
<td>--</td>
<td>2 (?)</td>
<td>7.14 g</td>
</tr>
<tr>
<td>W 53</td>
<td>KW 3634</td>
<td>16.78 g (-)</td>
<td>--</td>
<td>2 (?)</td>
<td>8.39 g</td>
</tr>
<tr>
<td>W 54</td>
<td>KW 3834</td>
<td>18.70 g</td>
<td>--</td>
<td>2</td>
<td>9.35 g</td>
</tr>
</tbody>
</table>
Table 6, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 55</td>
<td>KW 493</td>
<td>18.78 g</td>
<td>--</td>
<td>2</td>
<td>9.39 g</td>
</tr>
<tr>
<td>W 56</td>
<td>KW 1812</td>
<td>18.82 g</td>
<td>--</td>
<td>2</td>
<td>9.41 g</td>
</tr>
<tr>
<td>W 57</td>
<td>KW 2762</td>
<td>18.70 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.83 g (cal.)</td>
<td>--</td>
<td>2</td>
<td>9.42 g (cal.)</td>
</tr>
<tr>
<td>W 58</td>
<td>KW 4546</td>
<td>18.83 g</td>
<td>--</td>
<td>2</td>
<td>9.42 g</td>
</tr>
<tr>
<td>W 59</td>
<td>KW 4272</td>
<td>19.62 g</td>
<td>--</td>
<td>2</td>
<td>9.81 g</td>
</tr>
<tr>
<td>W 60</td>
<td>KW 788</td>
<td>19.88 g (-)</td>
<td>--</td>
<td>2</td>
<td>9.94 g (-)</td>
</tr>
<tr>
<td>W 61</td>
<td>KW 323</td>
<td>22.02 g</td>
<td>--</td>
<td>3 (? )</td>
<td>7.34 g</td>
</tr>
<tr>
<td>W 62</td>
<td>KW 1771</td>
<td>18.69 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.56 g (est.)</td>
<td>--</td>
<td>3 (? )</td>
<td>8.52 g (est.)</td>
</tr>
<tr>
<td>W 63</td>
<td>KW 4944</td>
<td>25.25 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.96 g (cal.)</td>
<td>--</td>
<td>3 (? )</td>
<td>8.65 g (cal.)</td>
</tr>
<tr>
<td>W 64</td>
<td>KW 521</td>
<td>27.28 g</td>
<td>--</td>
<td>3</td>
<td>9.09 g</td>
</tr>
<tr>
<td>W 65</td>
<td>KW 794</td>
<td>27.40 g</td>
<td>--</td>
<td>3</td>
<td>9.13 g</td>
</tr>
<tr>
<td>W 66</td>
<td>KW 4369</td>
<td>27.90 g</td>
<td>--</td>
<td>3</td>
<td>9.3 g</td>
</tr>
<tr>
<td>W 67</td>
<td>KW 3972</td>
<td>27.93 g</td>
<td>--</td>
<td>3</td>
<td>9.31 g</td>
</tr>
<tr>
<td>W 68</td>
<td>KW 1168</td>
<td>27.98 g (-)</td>
<td>--</td>
<td>3</td>
<td>9.33 g (-)</td>
</tr>
<tr>
<td>W 69</td>
<td>KW 3196</td>
<td>28.13 g</td>
<td>--</td>
<td>3</td>
<td>9.38 g</td>
</tr>
<tr>
<td>W 70</td>
<td>KW 3238</td>
<td>15.76 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28.30 g (est.)</td>
<td>--</td>
<td>3 (? )</td>
<td>9.43 g (est.)</td>
</tr>
<tr>
<td>W 71</td>
<td>KW 5751</td>
<td>28.75 g</td>
<td>--</td>
<td>3</td>
<td>9.58 g</td>
</tr>
<tr>
<td>W 72</td>
<td>Lot 2801</td>
<td>28.86 g (-)</td>
<td>--</td>
<td>3</td>
<td>9.62 g (-)</td>
</tr>
<tr>
<td>W 73</td>
<td>KW 325</td>
<td>28.94 g</td>
<td>--</td>
<td>3</td>
<td>9.65 g</td>
</tr>
<tr>
<td>W 74</td>
<td>KW 3765</td>
<td>29.11 g</td>
<td>--</td>
<td>3</td>
<td>9.70 g</td>
</tr>
<tr>
<td>W 75</td>
<td>KW 492</td>
<td>22.41 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30.05 g (est.)</td>
<td>--</td>
<td>3 (? )</td>
<td>10.02 g (est.)</td>
</tr>
<tr>
<td>W 76</td>
<td>KW 4438</td>
<td>41.63 g</td>
<td>--</td>
<td>5 (? )</td>
<td>8.33 g</td>
</tr>
<tr>
<td>W 77</td>
<td>KW 4214</td>
<td>42.21 g</td>
<td>--</td>
<td>5 (? )</td>
<td>8.44 g</td>
</tr>
</tbody>
</table>
Table 6, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 78</td>
<td>KW 564</td>
<td>37.83 g (-)</td>
<td>--</td>
<td>--</td>
<td>8.48 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42.41 g (est.)</td>
<td></td>
<td>5 (?)</td>
<td></td>
</tr>
<tr>
<td>W 79</td>
<td>KW 487</td>
<td>42.62 g (-)</td>
<td>--</td>
<td>5 (?)</td>
<td>8.52 g (-)</td>
</tr>
<tr>
<td>W 80</td>
<td>KW 3047</td>
<td>43.16 g (-)</td>
<td>--</td>
<td>--</td>
<td>8.73 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43.66 g (est.)</td>
<td></td>
<td>5 (?)</td>
<td></td>
</tr>
<tr>
<td>W 81</td>
<td>KW 967</td>
<td>45.62 g</td>
<td>--</td>
<td>5</td>
<td>9.12 g</td>
</tr>
<tr>
<td>W 82</td>
<td>KW 3467</td>
<td>45.65 g</td>
<td>--</td>
<td>5</td>
<td>9.13 g</td>
</tr>
<tr>
<td>W 83</td>
<td>KW 4125</td>
<td>45.82 g</td>
<td>--</td>
<td>5</td>
<td>9.16 g</td>
</tr>
<tr>
<td>W 84</td>
<td>KW 3839</td>
<td>45.84 g</td>
<td>--</td>
<td>5</td>
<td>9.17 g</td>
</tr>
<tr>
<td>W 85</td>
<td>KW 336</td>
<td>46.24 g</td>
<td>--</td>
<td>5</td>
<td>9.25 g</td>
</tr>
<tr>
<td>W 86</td>
<td>KW 377</td>
<td>46.38 g (-)</td>
<td>--</td>
<td>--</td>
<td>9.32 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>46.61 g (cal.)</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>W 87</td>
<td>KW 4547</td>
<td>46.51 g</td>
<td>--</td>
<td>5</td>
<td>9.30 g</td>
</tr>
<tr>
<td>W 88</td>
<td>KW 4368</td>
<td>46.79 g</td>
<td>--</td>
<td>5</td>
<td>9.36 g</td>
</tr>
<tr>
<td>W 89</td>
<td>KW 3801</td>
<td>47.02 g</td>
<td>--</td>
<td>5</td>
<td>9.40 g</td>
</tr>
<tr>
<td>W 90</td>
<td>KW 775</td>
<td>47.31 g (-)</td>
<td>--</td>
<td>--</td>
<td>9.57 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>47.85 g (cal.)</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>W 91</td>
<td>KW 4964</td>
<td>73.89 g</td>
<td>--</td>
<td>8 (?)</td>
<td>9.24 g</td>
</tr>
<tr>
<td>W 92</td>
<td>KW 874</td>
<td>76.04 g (-)</td>
<td>--</td>
<td>--</td>
<td>9.12 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.09 g (est.)</td>
<td></td>
<td>9 (?)</td>
<td></td>
</tr>
<tr>
<td>W 93</td>
<td>KW 1171</td>
<td>85.49 g (-)</td>
<td>--</td>
<td>9 (?)</td>
<td>9.50 g (-)</td>
</tr>
<tr>
<td>W 94</td>
<td>KW 3232</td>
<td>87.12 g (-)</td>
<td>--</td>
<td>9 (?)</td>
<td>9.68 g (-)</td>
</tr>
<tr>
<td>W 95</td>
<td>KW 3978</td>
<td>90.08 g</td>
<td>--</td>
<td>10</td>
<td>9.01 g</td>
</tr>
<tr>
<td>W 96</td>
<td>KW 174</td>
<td>90.30 g</td>
<td>Ψ</td>
<td>10</td>
<td>9.03 g</td>
</tr>
<tr>
<td>W 97</td>
<td>KW 5151</td>
<td>91.37 g</td>
<td>--</td>
<td>10</td>
<td>9.14 g</td>
</tr>
<tr>
<td>W 98</td>
<td>KW 863</td>
<td>91.61 g</td>
<td>--</td>
<td>10</td>
<td>9.16 g</td>
</tr>
<tr>
<td>W 99</td>
<td>KW 1737</td>
<td>91.68 g</td>
<td>--</td>
<td>10</td>
<td>9.17 g</td>
</tr>
<tr>
<td>W 100</td>
<td>KW 3800</td>
<td>92.43 g</td>
<td>--</td>
<td>10</td>
<td>9.24 g</td>
</tr>
</tbody>
</table>
Table 6, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 101</td>
<td>KW 5215</td>
<td>92.43 g (-)</td>
<td>--</td>
<td>10</td>
<td>9.24 g (-)</td>
</tr>
<tr>
<td>W 102</td>
<td>KW 3315</td>
<td>91.67 g (-)</td>
<td>--</td>
<td>--</td>
<td>9.25 g (cal.)</td>
</tr>
<tr>
<td>W 103</td>
<td>KW 935</td>
<td>92.51 g</td>
<td>--</td>
<td>10</td>
<td>9.25 g</td>
</tr>
<tr>
<td>W 104</td>
<td>KW 3299</td>
<td>92.61 g (-)</td>
<td>--</td>
<td>10</td>
<td>9.26 g (-)</td>
</tr>
<tr>
<td>W 105</td>
<td>KW 153</td>
<td>93.03 g</td>
<td>--</td>
<td>10</td>
<td>9.30 g</td>
</tr>
<tr>
<td>W 106</td>
<td>KW 774</td>
<td>93.17 g</td>
<td>--</td>
<td>10</td>
<td>9.32 g</td>
</tr>
<tr>
<td>W 107</td>
<td>KW 2001</td>
<td>94.65 g (+)</td>
<td>--</td>
<td>10</td>
<td>9.47 g</td>
</tr>
<tr>
<td>W 108</td>
<td>KW 459</td>
<td>139.51 g (-)</td>
<td>--</td>
<td>15</td>
<td>9.30 g (-)</td>
</tr>
<tr>
<td>W 109</td>
<td>KW 298</td>
<td>155.48 g (-)</td>
<td>--</td>
<td>15</td>
<td>10.36 g</td>
</tr>
<tr>
<td>W 110</td>
<td>KW 3840</td>
<td>160.49 g (-)</td>
<td>--</td>
<td>15</td>
<td>10.70 g</td>
</tr>
<tr>
<td>W 111</td>
<td>KW 1979</td>
<td>172.05 g (-)</td>
<td>--</td>
<td>20 (? )</td>
<td>8.60 g</td>
</tr>
<tr>
<td>W 112</td>
<td>KW 1917</td>
<td>182.30 g (-)</td>
<td>--</td>
<td>20</td>
<td>9.16 g (cal.)</td>
</tr>
<tr>
<td>W 113</td>
<td>KW 2696</td>
<td>184.33 g</td>
<td>--</td>
<td>20</td>
<td>9.22 g</td>
</tr>
<tr>
<td>W 114</td>
<td>KW 3233</td>
<td>185.04 g</td>
<td>--</td>
<td>20</td>
<td>9.25 g</td>
</tr>
<tr>
<td>W 115</td>
<td>KW 5737</td>
<td>183.83 g (-)</td>
<td>--</td>
<td>20</td>
<td>9.26 g (cal.)</td>
</tr>
<tr>
<td>W 116</td>
<td>KW 857</td>
<td>185.64 g</td>
<td>--</td>
<td>20</td>
<td>9.28 g</td>
</tr>
<tr>
<td>W 117</td>
<td>KW 3279</td>
<td>185.68 g</td>
<td>--</td>
<td>20</td>
<td>9.28 g</td>
</tr>
<tr>
<td>W 118</td>
<td>KW 3195</td>
<td>186.74 g</td>
<td>--</td>
<td>20</td>
<td>9.34 g</td>
</tr>
<tr>
<td>W 119</td>
<td>KW 3343</td>
<td>187.43 g</td>
<td>--</td>
<td>20</td>
<td>9.37 g</td>
</tr>
<tr>
<td>W 120</td>
<td>KW 3501</td>
<td>275.79 g</td>
<td>L</td>
<td>30</td>
<td>9.19 g</td>
</tr>
<tr>
<td>W 121</td>
<td>KW 578</td>
<td>278.61 g</td>
<td>--</td>
<td>30</td>
<td>9.28 g</td>
</tr>
<tr>
<td>W 122</td>
<td>KW 571</td>
<td>278.63 g</td>
<td>--</td>
<td>30</td>
<td>9.29 g</td>
</tr>
<tr>
<td>W 123</td>
<td>KW 3099</td>
<td>323.57 g (-)</td>
<td>--</td>
<td>35 (?)</td>
<td>9.24 g</td>
</tr>
<tr>
<td>W 124</td>
<td>KW 4165</td>
<td>456.48 g</td>
<td>L</td>
<td>50</td>
<td>9.13 g</td>
</tr>
</tbody>
</table>
Table 6, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Field No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 125</td>
<td>KW 710</td>
<td>458.54 g</td>
<td>--</td>
<td>50</td>
<td>9.17 g</td>
</tr>
<tr>
<td>W 126</td>
<td>KW 382</td>
<td>460.32 g (-)</td>
<td>--</td>
<td>50</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>462.40 g (cal.)</td>
<td></td>
<td></td>
<td>9.25 g (cal.)</td>
</tr>
<tr>
<td>W 127</td>
<td>KW 477</td>
<td>916.7 g</td>
<td>--</td>
<td>100</td>
<td>9.17 g</td>
</tr>
<tr>
<td>W 128</td>
<td>KW 1511</td>
<td>923.2 g (-)</td>
<td>--</td>
<td>100</td>
<td>9.26 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>925.6 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 129</td>
<td>KW 849</td>
<td>2,483 ± 2 g (-)</td>
<td>--</td>
<td>250 (?)</td>
<td>9.93 g (-)</td>
</tr>
<tr>
<td>W 130</td>
<td>KW 830</td>
<td>7,632 ± 2 g</td>
<td>--</td>
<td>800 (?)</td>
<td>9.54 g</td>
</tr>
</tbody>
</table>

Table 6 can be summarized in graphs that plot the masses of the well-preserved weights against predicted fractions and multiples of 9.4 g. To facilitate the plotting of the many weight pieces of the Uluburun assemblage without excessively cluttering the graphs, however, it has been necessary to separate them into their respective morphological groups: the sphendonoid weights and the domed weights. Accordingly, figures 5 and 7 plot sphendonoid and domed weights of up to 20 g in mass, while figure 6 shows sphendonoids in the range of 21 g to 100 g, and figure 8 includes all domed weights between 21 g and 950 g. Each mark on the diagonal axes represents the mass of one weight piece. Clearly, most of the intact 92 Uluburun sphendonoid and domed weights form coherent clusters corresponding to calculated fractions and multiples of a standard unit mass of ca. 9.4 g. That the Uluburun weight assemblage comprises several independent sets is clearly suggested by the much larger than necessary number of weight pieces corresponding to the same multiple-unit denominations.
**Quantal Search**

The foregoing intuitive analysis has addressed all of the well-preserved balance weights from Uluburun and has tested for plausible and logical utilitarian relationships among them. I have speculated about possible attributions of weight pieces, especially those of fractional units, as well as of some pieces that are damaged but restored to their approximate original masses. On an intuitive level, it would appear that we have overwhelming evidence for the existence of a system based on a unit mass of ca. 9.4 g.

Let us now examine objectively, through quantal analysis, the population of weights listed in table 6, but after removing those weights that are damaged (W 31 [KW 1854], W 42 [KW 731], W 63 [KW 4944], W 72 [Lot 2801], W 102 [KW 3315], W 123 [KW 3099]), contain or once contained lead plugs (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]) or bore other metal components such as suspension loops (W 46 [KW 5143], W 107 [KW 2001]), or are of bronze (W 5 [KW 337], W 7 [KW 1223], W 8 [KW 2891], W 12 [KW 503], W 16 [Lot 918], W 21 [KW 4323], W 25 [KW 467], W 26 [KW 768], W 32 [KW 4424], W 39 [KW 3836], W 53 [KW 3634], W 62 [KW 1771], W 70 [KW 3238], W 75 [KW 492], W 77 [KW 4214], W 78 [KW 564], W 80 [KW 3047], W 92 [KW 874], W 110 [KW 3840]) or lead (W 60 [KW 788], W 68 [KW 1168], W 79 [KW 487], W 93 [KW 1171], W 108 [KW 459], W 109 [KW 298], W 111 [KW 1979], W 129 [KW 849]). The zoomorphic group is also excepted, as all 19 pieces are bronze or bronze with lead cores. The very heavy W 130 (KW 830), of 7,632 ± 2 g, has also been excluded from the quantal search because of its unique size and mass. To the above 58 weights excluded from our quantal analysis, three other pieces (W 23 [KW 2784], W 73 [KW 325], W 91 [KW 4964]) should be added. They are in good condition, but are provided with holes for suspension. It is possible, therefore, that they were originally fitted with metal loops that would have rendered them heavier than their current masses. The largest of the three pieces (W 91 [KW 4964]), which weighs 73.89 g, is similar in shape and with regard to the location of its suspension
hole to two other specimens in the Uluburun assemblage (W 46 [KW 5143] and W 107 [KW 2001]), which also were eliminated from the list of viable weights due to the presence of metal suspension loops. Unless weight W 91 (KW 4964) is based on a standard other than one with a unit mass of ca. 9.4 g (i.e., 10 units of 7.34 g), it does not correspond to any plausible multiple units of that standard. Indeed, it may have been originally equipped with a now lost metal ring similar to those on W 46 [KW 5143] and W 107 [KW 2001]. Disk weight W 73 (KW 325) and scarab W 23 (KW 2784), on the other hand, are hematite pieces pierced through their diameters. This configuration is similar to that found on certain seals or beads that were strung to be worn around one's wrist or neck rather than suspended from metal loops. If such is the case for these two items, their respective masses of 28.94 g and 6.04 g probably correspond to 3 units of 9.65 g, and 2/3 of a unit of 9.06 g. These values are somewhat on the heavier and lighter sides of 9.4 g, but are within the accepted limits of the Ugaritic shekel.

A note is in order here regarding five hematite weights (W 57 [KW 2762], W 90 [KW 775], W 112 [KW 1917], W 115 [KW 5737], W 128 [KW 1511]) that are slightly damaged but included in the statistical analysis with their calculated masses. Because the difference between their respective preserved and restored masses is 1.1% or less, the effect on the outcome will be considered negligible. Also, we will assume that no weight piece was more accurately manufactured than any other.

Based on our knowledge of mass standards in use in the Mediterranean during the Bronze Age, if our quantal search was limited to values between 2 g and 75 g, we would clearly cover all systems and fractional values thereof. By subjecting the complete assemblage of well-preserved weights from Uluburun to such a wide range of possible mass standards, and without restricting the quantal search to any specific morphological group, one should be able to assess objectively what tested quanta give the highest peaks or maxima (values that yield the lowest error term), and which thus correspond to the most likely standard unit mass of the weight population as a whole.
A quantal search, using Kendall’s statistic, among the 85 intact, non-pierced, non-metallic weights from Uluburun gives the peaks plotted in figure 5. They are given in the order of highest positive value to lowest (i.e., lowest error term to highest) in table 7.

The two highest peaks of the quantal search correspond to 46.1 g and 23.0 g, respectively. The first quantum probably represents 5 units of 9.2 g or, perhaps, 6 units of 7.7 g, while the second peak could represent 2 units of 11.5 g or 3 units of 7.7 g. The third peak yields 9.3 g precisely, approximately the value of the Ugaritic shekel, or qedet, to which we have assigned most of the Uluburun weights based on intuitive analysis. Even the quantum of 46.1 g may be taken as an indicator of the presence of a unit mass in the vicinity of ca. 9.4 g, as this quantum most likely

Fig. 5. Plotted results of Kendall’s statistic for the 85 intact weight pieces from Uluburun.
Table 7. Peak values corresponding to the quanta most likely to be represented among the 85 intact weight pieces from Uluburun.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46.1 g</td>
<td>$\Phi(t) = +6.443$</td>
<td>5 of 9.2 g or 6 of 7.7 g</td>
</tr>
<tr>
<td>2</td>
<td>23.0 g</td>
<td>$\Phi(t) = +4.460$</td>
<td>2 of 11.5 g or 3 of 7.7 g</td>
</tr>
<tr>
<td>3</td>
<td>9.3 g</td>
<td>$\Phi(t) = +3.796$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5.8 g</td>
<td>$\Phi(t) = +3.117$</td>
<td>2/3 of 8.7 g or 1/2 of 11.6 g</td>
</tr>
<tr>
<td>5</td>
<td>30.7 g</td>
<td>$\Phi(t) = +2.774$</td>
<td>2 of 15.4 g or 3 of 10.2 g or 4 of 7.7 g</td>
</tr>
<tr>
<td>6</td>
<td>2.1 g</td>
<td>$\Phi(t) = +2.592$</td>
<td>1/4 of 8.4 g</td>
</tr>
<tr>
<td>7</td>
<td>57.5 g</td>
<td>$\Phi(t) = +2.557$</td>
<td>6 of 9.6 g</td>
</tr>
<tr>
<td>8</td>
<td>15.4 g</td>
<td>$\Phi(t) = +2.543$</td>
<td>1 or 1/2 of 7.7 g</td>
</tr>
<tr>
<td>9</td>
<td>65.7 g</td>
<td>$\Phi(t) = +2.492$</td>
<td>7 of 9.4 g or 8 of 8.2 g or 1 of 65.7 g</td>
</tr>
<tr>
<td>10</td>
<td>4.6 g</td>
<td>$\Phi(t) = +2.344$</td>
<td>1/2 of 9.2 g</td>
</tr>
</tbody>
</table>

represents the more utilitarian 5 units of 9.2 g rather than 6 units of 7.7 g, a multiple not attested for in that standard. But, that a second standard based on a unit mass of ca. 7.7 g may also be represented is strongly suggested by the occurrence or possible occurrence of that value at the first, second, fifth, and eighth peaks. That yet a third mass standard, in the vicinity of 8.4 g, may be present in the Uluburun weight assemblage is hinted at by the fourth peak of 5.8 g, which could correspond to 2/3 of 8.7 g or 1/2 of 11.6 g, and by the sixth peak of 2.1 g that perhaps represents 1/4 of 8.4 g.

It is clear that Kendall's statistic is incapable, in some instances, of segregating
different norms in an assemblage (see Appendix A). Based on this quantal search among only the well-preserved, non-metal weights from Uluburun, irrespective of size and shape, there could be as many as three different mass standards represented. The presence of one based on a unit mass of ca. 9.3 g is the most strongly felt and is the norm to which the great majority of the Uluburun weights conform. This unit mass probably represents the Ugaritic/Syrian shekel, a standard that was undoubtedly based on the Egyptian qedet, and commonly used all along the Syro-Palestinian coast, especially in the north, and on Cyprus. A second standard based on a unit mass of ca. 7.7 g is also probably represented, but not as strongly. Perhaps a limited number of weight pieces thus conform to the standard known as the peyem, which ranges from 7.4 g to about 8 g. A third standard based on a unit mass of ca. 8.7 g, probably corresponding to the Mesopotamian shekel, is even more weakly suggested by our quantal search. These mass standards are discussed in greater detail in Chapter II.

Thus, all of the possible candidates for the unit masses of the standards revealed by Kendall’s statistic correspond to known Near Eastern mass systems or their multiple or fractional units. The only suspect quantum, which raises the slim possibility of the presence of an Aegean system of mass mensuration, is the value of 65.7 g that corresponds to the ninth-highest peak in the spectrum. This value should probably be interpreted as 7 units of ca. 9.4 g or 8 units of 8.2 g, though it could be viewed as 1 unit of the Aegean system based on a unit mass of 65 or 66 g. Petruzzo (1992), in his study of weight pieces primarily from Ayia Irini on Keos, but also other Aegean sites, makes a convincing case for an Aegean standard with a unit mass in the vicinity of 61 g. The quantum of 65.7 g would be somewhat on the heavy side, but the mass range for this system is not yet fully understood, and such heavy pieces do exist in the Aegean. Still, it is more likely that this value represents 7 units of 9.4 g, rather than the Aegean standard, because although no 7-unit pieces are found in the Uluburun weight assemblage, these peculiar units are present in some numbers among the sphendonoid weights from Cape Gelidonya. This issue will be treated in detail in
Chapter IV.

A second quantal search (fig. 6, table 8) includes five hematite weight pieces (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]) with lead plugs and three damaged weight pieces (W 42 [KW 731], W 63 [KW 4944], W 102 [KW 3315]) with their restored masses. It should be noted that the weights in the first group may be somewhat underweight, but the lead plug of each weight is still present, and the deviation of each piece from its original mass is probably negligible.

![Graph](image_url)

Fig. 6. Plotted results of Kendall’s statistic for intact weights, weights with lead plugs (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]), and damaged weights with their restored masses (W 42 [KW 731], W 63 [KW 4944], W 102 [KW 3315]) from Uluburun.
Table 8. Peak values corresponding to the quanta most likely to be represented among intact weights, weights with lead plugs (W 36 [KW 2336], W 40 [KW 227], W 94 [KW 3232], W 101 [KW 5215], W 104 [KW 3299]), and weights with restored masses (W 42 [KW 731], W 63 [KW 4944], W 102 [KW 3315]) from Uluburun.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46.1 g</td>
<td>$\Phi(\tau) = +6.706$</td>
<td>5 (?) of 9.2 g or 6 (?) of 7.7 g</td>
</tr>
<tr>
<td>2</td>
<td>23.0 g</td>
<td>$\Phi(\tau) = +4.483$</td>
<td>2 (?) of 11.5 g or 3 (?) of 7.7 g</td>
</tr>
<tr>
<td>3</td>
<td>9.3 g</td>
<td>$\Phi(\tau) = +4.336$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5.8 g</td>
<td>$\Phi(\tau) = +3.236$</td>
<td>2/3 (?) of 8.7 g or 1/2 (?) of 11.6 g</td>
</tr>
<tr>
<td>5</td>
<td>30.7 g</td>
<td>$\Phi(\tau) = +3.108$</td>
<td>1/4 (?) of 7.7 g</td>
</tr>
<tr>
<td>6</td>
<td>4.6 g</td>
<td>$\Phi(\tau) = +2.750$</td>
<td>1/2 (?) of 9.2 g</td>
</tr>
<tr>
<td>7</td>
<td>2.1 g</td>
<td>$\Phi(\tau) = +2.702$</td>
<td>1/4 (?) of 8.4 g</td>
</tr>
<tr>
<td>8</td>
<td>6.6 g</td>
<td>$\Phi(\tau) = +2.540$</td>
<td>1/2 (?) of 13.2 g</td>
</tr>
<tr>
<td>9</td>
<td>42.1 g</td>
<td>$\Phi(\tau) = +2.161$</td>
<td>5 (?) of 8.4 g</td>
</tr>
<tr>
<td>10</td>
<td>65.8 g</td>
<td>$\Phi(\tau) = +2.107$</td>
<td>7 (?) of 9.4 g or 1 (?)</td>
</tr>
</tbody>
</table>

The second quantal search produces no significant shift in the overall results. In fact, the first five peaks are identical to those of the first search. The unit mass of 9.3 g still ranks third, but is better represented in this instance, as indicated by an error term (+ 4.336) that is only 0.147 lower than that of the quantum in second position. It is certain that this increase is partly due to the increased size of the population submitted to the analysis (see Appendix A), but a standard unit mass in the vicinity of 9.3 g is also strongly indicated by the first, third, sixth, and tenth peaks. That other standards based on unit masses of ca. 7.7 g and ca. 8.4 g are represented remains likely as well, as they have retained their ranking. Clearly, had the value of the Ugaritic/Syrian shekel, and its parent norm the Egyptian qedet, not already been
established by previous research, that mass would have been the best candidate for the Uluburun system standard. While the proposed system for these weights accounts for the majority of the specimens from the site, however, it by no means accounts for all of them.

The Basic Weight Groups

Having demonstrated statistically that a mass of ca. 9.3 g is probably the unit mass of a system represented by the great majority of Uluburun balance weights, and that norms of ca. 7.7 g and ca. 8.4 g are also in evidence, it now remains to show that the weight pieces conforming to these norms constitute different groups and that each group comprises one or more weight sets with sufficient individual elements of various denominations to conveniently and effectively carry out most weighing operations. As the Uluburun weight assemblage is the largest and most complete group of contemporaneous Late Bronze Age weights to have come from a closed-context site, all standards and sets necessary for an effective maritime merchant venture might be expected. Further, unlike the nearly contemporary but slightly more recent shipwreck at Cape Gelidonya, where the ship actually started to break up and spill its contents before it sank, all evidence from the excavations at Uluburun indicates that the ship sank intact. Therefore, nearly all the weight pieces originally carried aboard probably went down with the ship and were recovered in the course of excavations. A few pieces undoubtedly could have been missed, especially the smaller denominations, and some of the metal specimens may have been transformed into amorphous corrosion products or lumps that could not be recognized as weight specimens, or disintegrated completely. Yet it is reasonable to assume for Uluburun that nearly all the non-metallic weight pieces carried aboard the ship were recovered and that most of the various weight sets are complete or nearly complete.

That the Uluburun weight assemblage includes elements of many sets is amply suggested by the much larger than necessary number of weight specimens representing
some of the multiple-unit denominations. For example there are 13 1-unit pieces and as many as 20 specimens may be represented if all mass standards are taken into consideration. Similarly, there are 10 5-unit pieces (15 with all standards), and at least a dozen 3-unit pieces, with two additional specimens if all standards are included. It is clear, therefore, that there may be as many as a dozen sets present, if each set contains only one of each denomination, or half as many if the denominations are duplicated in a set. In an attempt to discern the individual balance weight sets represented in the Uluburun weight assemblage, we begin by separating the weights into two major groups based on shape: the sphendonoid group and the domed group. This of course assumes that distinctively fashioned weight pieces can be easily recognized as representing different standards or systems (Petruso 1984: 295). Unfortunately, not all our weights lend themselves to such easy sorting. Intermediary forms that defy facile attribution to either group, as well as irregular shapes that cannot be conveniently placed in either group, exist in some numbers. For the most part, their assignations to either of these groups are purely subjective. For all practical purposes, therefore, in addition to pieces in the typical sphendonoid shape, the sphendonoid weight group will comprise all non-circular weights. That is to say, all balance weights that are sphendonoid, ovoid, rectangular, square, bread-loaf, irregular, or oblong in shape. Similarly, the domed group will comprise all weights of circular top view shape (except lead disks), whether it has a domed top or not. Thus, weights that have been previously cataloged as domed, dome-topped, cupcake, sugar loaf, and disk, all of which occur in the Uluburun assemblage, will be included in the domed group. While this division may appear to be too general for a detailed evaluation of the mass standards represented in the respective groups, it is only a first step toward their ascertainment and interpretation. The logic behind such broad groupings is that oblong objects may be separated conveniently and quickly from those that are circular in shape. When we have established our two major categories of balance weights, the next step will be to isolate within them any specific morphological types that could
help us detect individual weight sets.

*The Sphendonoid Weights.* On the Uluburun ship there are nearly twice as many sphendonoid balance weights (81) as there are domed weights (44, including three of lead). What is immediately apparent in the sphendonoid assemblage is that they represent smaller denominations, with no less than 33 (40.7%) of ca. 10 g or less in mass, and that no weights may be attributed to more than 10 units (of ca. 9.3 g). Clearly, the sphendonoid pieces were used primarily for weighing quantities of merchandise smaller than those weighed with the domed weights, which include denominations of up to 100 units. This merchandise almost certainly included precious metals such as gold, silver, and perhaps also spices, all of which were found in quantity on the wreck.

It is noteworthy that 15 (18.1%) of the sphendonoid weights and 19 (12.8%) of all non-zoomorphic Uluburun weights are of bronze. This proportion appears somewhat high, especially when one considers the infrequent occurrence of bronze balance weights on terrestrial Near Eastern sites. It seems, then, that while Petrie’s contention that balance weights of metal were rarely used before the Classical Greek period (Petrie 1926: 22) is probably correct, the Uluburun weight assemblage indicates that even though stone weights were preferred over those of metal, the latter were used perhaps more frequently than previously believed. The most likely explanation for the scarcity of metal weights on terrestrial Bronze Age sites, then, is that metal was always considered a valuable material with recycling potential, and that many metal weights must have been thrown into the crucible to be melted down and recast into other objects. For comparison, we note that of the 566 weight pieces from Ras Shamra/Ugarit only 30 (5.3%) pieces, of both sphendonoid and domed shape, are of bronze (Courtois 1990: 119).

That nearly a fifth of the sphendonoid weights are of bronze and therefore underweight due to corrosion, and that they represent mostly small and fractional
units, compounds the problem of ascertaining with ease their standard unit masses and denominations. Unlike the Uluburun domed weights, which, for the most part, fall into neat clusters centered on calculated multiples of a single standard unit mass (see below), the sphendonoid balance weights do not lend themselves to such straightforward attributions. As may be expected, many of the sphendonoid weight pieces conform to fractional and multiple units of the Ugaritic/Syrian shekel of ca. 9.3-9.4 g, the same standard found among the Uluburun domed weights. Unlike the domed weights, however, the heaviest weights are only 10-unit pieces, and there are far more fractional units. Furthermore, our quantal searches suggest there are many specimens not easily attributable to the Ugaritic/Syrian standard that almost certainly represent other standards of mensuration that were concurrently used in the region. The problem of attributing these weights to specific mass standards at the fractional level is further exacerbated not only by the presence of underweight metal weights, but also by the fact that the fractional weight pieces of the various standards represented appear to overlap in most instances, and clear-cut divisions are not always apparent. This difficulty is inherent in the very nature of fractional weights. Because the pieces represent only fractions of a particular standard unit(s), the differences in their masses are considerably less, hence the difficulties of separation. Moreover, the presumably diminished accuracy of ancient balances when weighing lighter masses results in fractional balance weights with proportionally larger deviations from their norm values. A peculiarity also evident in the Uluburun weights, especially among the domed pieces, is that for a collection of balance weights that closely approximates the theoretical masses of 9.3-g multiples, masses at the 1-unit mass level are significantly greater than what is expected for the norm. All balance weights in the Uluburun sphendonoid group that cluster near ca. 9.3 g are overweight if they indeed do represent the unit mass. In fact, while there are several weight specimens attributable to every 9.3-g multiple in the assemblage, there are really no good, reasonably accurate or acceptable candidates among the thirteen weights that are likely to
represent this unit mass, save the possible exception of W 40 (KW 227), which weighs 9.64 g. Even this weight piece, fitted with a lead plug for fine adjustment of its mass, is probably somewhat lighter than originally intended, as its leaden component has undoubtedly suffered some corrosion. The next-closest weight piece, W 41 (KW 729) of 10.28 g, on the other hand, is nearly 1 g (ca. 10%) heavier than the mean for its norm. As with the domed weights, which show a similar pattern, we are unable to provide a convincing explanation for this seemingly anomalous and perplexing situation.

In addition to the Ugaritic/Syrian standard, the Eblite or Paleo-Syrian (peyem) standard, with a unit mass of ca. 7.6 g, and the Mesopotamian standard unit mass of ca. 8.2 g, seem to be represented among the Uluburun sphendonoids. Both of these standards are attested at Ugarit with mean unit masses of 7.8 g and 8.4 (8-8.5) g, respectively.

Balance weights W 51 (KW 4310) and W 48 (KW 803), with masses of 11.09 g and 10.75 g, respectively, are too heavy to be units of the Ugaritic/Syrian standard and too light to be multiple units of the three standards evidently represented among the Uluburun weights. It is possible that these two weights represent unit masses of yet a fourth standard, the necef of ca. 10.5 g.

We lack any well-preserved, usable, marked balance weights that could assist us in determining the unit masses represented in the sphendonoid group. That many of the higher sphendonoid masses cluster near the same mass values as do those of the domed weights suggests that most of the higher denominations represent the same standard mass of 9.3 g. Accordingly, we propose the following unit attributions and resultant unit masses for the Uluburun sphendonoid weights (table 9). The denominations generally indicate a decimal system with a unit mass in the vicinity of 9.3 g.
Table 9. The Uluburun sphendonoid weights with their likely unit attributions based on a unit mass of ca. 9.3 g and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 1 (KW 5136)</td>
<td>Limestone</td>
<td>1.56 g</td>
<td>--</td>
<td>1/6</td>
<td>9.36 g</td>
</tr>
<tr>
<td>2</td>
<td>W 4 (KW 5719)</td>
<td>Limonite/Goethite</td>
<td>2.96 g</td>
<td>--</td>
<td>1/3</td>
<td>8.88 g</td>
</tr>
<tr>
<td>3</td>
<td>W 17 (KW 955)</td>
<td>Limonite</td>
<td>4.67 g</td>
<td>--</td>
<td>1/2</td>
<td>9.34 g</td>
</tr>
<tr>
<td>4</td>
<td>W 18 (Lot 10968)</td>
<td>Hematite</td>
<td>4.79 g</td>
<td>--</td>
<td>1/2</td>
<td>9.58 g</td>
</tr>
<tr>
<td>5</td>
<td>W 21 (KW 4323)</td>
<td>Bronze</td>
<td>5.78 g (-)</td>
<td>--</td>
<td>2/3</td>
<td>8.84 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.89 g (est.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>W 22 (KW 2899)</td>
<td>Ilmenite (?)</td>
<td>5.97 g</td>
<td>--</td>
<td>2/3</td>
<td>8.96 g</td>
</tr>
<tr>
<td>7</td>
<td>W 23 (KW 2784)</td>
<td>Hematite</td>
<td>6.04 g</td>
<td>--</td>
<td>2/3</td>
<td>9.06 g</td>
</tr>
<tr>
<td>8</td>
<td>W 25 (KW 467)</td>
<td>Bronze</td>
<td>4.82 g (-)</td>
<td>1</td>
<td>2/3</td>
<td>9.35 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.23 g (est.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>W 27 (KW 966)</td>
<td>Hematite</td>
<td>6.59 g</td>
<td>--</td>
<td>2/3</td>
<td>9.89 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4</td>
<td>8.79 g</td>
</tr>
<tr>
<td>10</td>
<td>W 29 (KW 469)</td>
<td>Diorite (?)</td>
<td>6.88 g</td>
<td>--</td>
<td>2/3</td>
<td>10.32 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4</td>
<td>9.17 g</td>
</tr>
<tr>
<td>11</td>
<td>W 30 (KW 4184)</td>
<td>Hematite</td>
<td>6.94 g</td>
<td>--</td>
<td>2/3</td>
<td>10.41 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3/4</td>
<td>9.25 g</td>
</tr>
<tr>
<td>12</td>
<td>W 40 (KW 227)</td>
<td>Ilmenite(?)/Lead</td>
<td>9.64 g (-)</td>
<td>--</td>
<td>1</td>
<td>9.64 g (-)</td>
</tr>
<tr>
<td>13</td>
<td>W 41 (KW 729)</td>
<td>Hematite</td>
<td>10.28 g</td>
<td>--</td>
<td>1</td>
<td>10.28 g</td>
</tr>
<tr>
<td>14</td>
<td>W 42 (KW 731)</td>
<td>Kaolin or Argilite (?)</td>
<td>7.22 g (-)</td>
<td>--</td>
<td>1</td>
<td>10.29 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10.29 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>W 53 (KW 3634)</td>
<td>Bronze</td>
<td>16.78 g (-)</td>
<td>--</td>
<td>2 (?)</td>
<td>8.39 g (-)</td>
</tr>
<tr>
<td>16</td>
<td>W 55 (KW 493)</td>
<td>Hematite</td>
<td>18.78 g</td>
<td>--</td>
<td>2</td>
<td>9.39 g</td>
</tr>
<tr>
<td>17</td>
<td>W 56 (KW 1812)</td>
<td>Hematite</td>
<td>18.82 g</td>
<td>--</td>
<td>2</td>
<td>9.41 g</td>
</tr>
<tr>
<td>18</td>
<td>W 58 (KW 4546)</td>
<td>Hematite</td>
<td>18.83 g</td>
<td>--</td>
<td>2</td>
<td>9.42 g</td>
</tr>
<tr>
<td>19</td>
<td>W 65 (KW 794)</td>
<td>Hematite</td>
<td>27.40 g</td>
<td>--</td>
<td>3</td>
<td>9.13 g</td>
</tr>
<tr>
<td>20</td>
<td>W 69 (KW 3196)</td>
<td>Hematite</td>
<td>28.13 g</td>
<td>--</td>
<td>3</td>
<td>9.38 g</td>
</tr>
<tr>
<td>No.</td>
<td>Cat. No.</td>
<td>Material</td>
<td>Mass</td>
<td>Mark</td>
<td>Unit Attribution</td>
<td>Resultant Unit Mass</td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>----------</td>
<td>---------------</td>
<td>------</td>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>21</td>
<td>W 70 (KW 3238)</td>
<td>Bronze</td>
<td>15.76 g (-)</td>
<td>--</td>
<td>3</td>
<td>9.43 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28.30 (est.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>W 71 (KW 5751)</td>
<td>Hematite</td>
<td>28.75 g</td>
<td>--</td>
<td>3</td>
<td>9.58 g</td>
</tr>
<tr>
<td>23</td>
<td>W 72 (Lot 2801)</td>
<td>Hematite</td>
<td>28.86 g (-)</td>
<td>--</td>
<td>3</td>
<td>9.62 g (-)</td>
</tr>
<tr>
<td>24</td>
<td>W 74 (KW 3765)</td>
<td>Hematite</td>
<td>29.11 g</td>
<td>--</td>
<td>3</td>
<td>9.70 g</td>
</tr>
<tr>
<td>25</td>
<td>W 80 (KW 3047)</td>
<td>Bronze</td>
<td>43.16 g (-)</td>
<td>--</td>
<td>5</td>
<td>8.73 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>43.66 g (est.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>W 81 (KW 967)</td>
<td>Hematite</td>
<td>45.62 g</td>
<td>--</td>
<td>5</td>
<td>9.12 g</td>
</tr>
<tr>
<td>27</td>
<td>W 82 (KW 3467)</td>
<td>Hematite</td>
<td>45.65 g</td>
<td>--</td>
<td>5</td>
<td>9.13 g</td>
</tr>
<tr>
<td>28</td>
<td>W 83 (KW 4125)</td>
<td>Hematite</td>
<td>45.82 g</td>
<td>--</td>
<td>5</td>
<td>9.16 g</td>
</tr>
<tr>
<td>29</td>
<td>W 84 (KW 3839)</td>
<td>Hematite</td>
<td>45.84 g</td>
<td>--</td>
<td>5</td>
<td>9.17 g</td>
</tr>
<tr>
<td>30</td>
<td>W 85 (KW 336)</td>
<td>Diorite</td>
<td>46.24 g</td>
<td>--</td>
<td>5</td>
<td>9.25 g</td>
</tr>
<tr>
<td>31</td>
<td>W 86 (KW 377)</td>
<td>Hematite</td>
<td>46.38 g (-)</td>
<td>--</td>
<td>5</td>
<td>9.32 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>46.61 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>W 89 (KW 3801)</td>
<td>Ilmenite</td>
<td>47.02 g</td>
<td>--</td>
<td>5</td>
<td>9.40 g</td>
</tr>
<tr>
<td>33</td>
<td>W 90 (KW 775)</td>
<td>Hematite</td>
<td>47.31 g (-)</td>
<td>--</td>
<td>5</td>
<td>9.57 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47.85 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>W 94 (KW 3232)</td>
<td>Hematite/Lead</td>
<td>87.12 g (-)</td>
<td>--</td>
<td>10</td>
<td>8.71 g (-)</td>
</tr>
<tr>
<td>35</td>
<td>W 96 (KW 174)</td>
<td>Steatite</td>
<td>90.30 g (Ψ)</td>
<td>10</td>
<td>9.03 g</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>W 99 (KW 1737)</td>
<td>Hematite</td>
<td>91.68 g</td>
<td>--</td>
<td>10</td>
<td>9.17 g</td>
</tr>
<tr>
<td>37</td>
<td>W 100 (KW 3800)</td>
<td>Ilmenite</td>
<td>92.43 g</td>
<td>--</td>
<td>10</td>
<td>9.24 g</td>
</tr>
<tr>
<td>38</td>
<td>W 101 (KW 5215)</td>
<td>Hematite/Lead</td>
<td>92.43 g (-)</td>
<td>--</td>
<td>10</td>
<td>9.24 g (-)</td>
</tr>
<tr>
<td>39</td>
<td>W 102 (KW 3315)</td>
<td>Hematite</td>
<td>91.67 g (-)</td>
<td>--</td>
<td>10</td>
<td>9.25 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>92.49 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>W 103 (KW 935)</td>
<td>Ilmenite (?)</td>
<td>92.51 g</td>
<td>--</td>
<td>10</td>
<td>9.25 g</td>
</tr>
<tr>
<td>41</td>
<td>W 104 (KW 3299)</td>
<td>Hematite/Lead</td>
<td>92.61 g (-)</td>
<td>--</td>
<td>10</td>
<td>9.26 g (-)</td>
</tr>
<tr>
<td>42</td>
<td>W 107 (KW 2001)</td>
<td>Hematite/Tin</td>
<td>94.65 g (+)</td>
<td>--</td>
<td>10</td>
<td>9.47 g (+)</td>
</tr>
</tbody>
</table>
Mean resultant average of intact sphendonoids 9.35 g
Mean resultant average of all sphendonoids 9.33 g
Mean resultant weighted average of intact sphendonoids 9.25 g
Mean resultant weighted average of all sphendonoids 9.24 g
(Note: Averages do not include fractional denominations)

Because of their small masses, there is usually considerable overlap in the range of unit masses for the fractional denominations. As a result, their attributions to specific standards is always suspect; a weight specimen designated to conform to one mass standard may just as likely be a member of another. Attributions of fractional denominations, therefore, is always a suspect. For the reason mentioned, I have preferred not to include any of the fractional denomination in the calculation of average unit mass values following the subsequent tables. Moreover, as they are light specimens, their effect on the weighted average values for the standards would have been negligible. Bronze weight W 53 (KW 3634) of 16.78 g (-) was not included in the calculation of average values of all specimens; the specimen is considerably underweight and its poor condition has not allowed for the estimation of its original mass. The same may be said for hematite weight W 94 (KW 3232) , which is provided with a lead plug at its base for the fine adjustment of its mass. The weight itself is in excellent condition, but it is not possible to determine the amount of mass loss, if any, from the lead plug. Even so, this weight appears to be extremely underweight for a 10-unit piece based on a unit mass of ca. 9.3 g, but has been retained here because it is also too heavy to correspond to a 10 multiple of a standard based on a unit mass of ca. 8.4 g. Either way, its inclusion or exclusion in the calculation of unit mass averages does not change these values at the tenth-of-a gram level.

The resultant average of 9.35 g and the weighted average of 9.30 g for the intact sphendonoid weights seems to correspond well to the quantum of 9.3 g revealed by our statistical analysis incorporating all weights.

The denominational attributions of the sphendonoid weights from Uluburun are summarized in figures 7 and 8, which plot the masses of the intact sphendonoids
Fig. 7. Proposed fraction and multiple attributions of the standard unit mass of 9.3 g evident in the Uluburun sphendonoid weights in the range of 0 g to 15 g.
Fig. 8. Proposed multiple attributions of the standard unit mass of 9.3 g evident in the Uluburun sphendonoid weights in the range of 15 g to 100g.
against predicted fractions and multiples of a unit mass of 9.3 g. Again, each mark on the diagonals represents the mass of one balance weight. It is clear that many of the Uluburun sphendonoid weights form coherent clusters around multiples of 9.3 g. Dispersed among these clusters are other weight pieces that obviously are either significantly under- or overweight and probably represent fractions and/or multiples of other mass standards. For some of these weight pieces we propose the following unit attributions and resultant unit masses for a standard unit mass of ca. 7.4 g (table 10).

Table 10. Uluburun weight pieces of the sphendonoid group that appear to conform to a system with a standard unit mass of ca. 7.4 g, and their likely unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 6 (KW 3212)</td>
<td>Hematite</td>
<td>3.59 g</td>
<td>--</td>
<td>1/2</td>
<td>7.18 g</td>
</tr>
<tr>
<td>2</td>
<td>W 7 (KW 1223)</td>
<td>Bronze</td>
<td>0.82 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.74 g (est.)</td>
<td></td>
<td>1/2</td>
<td>7.48 g (est.)</td>
</tr>
<tr>
<td>3</td>
<td>W 8 (KW 2891)</td>
<td>Bronze</td>
<td>2.27 g (-)</td>
<td>I</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.90 g (est.)</td>
<td></td>
<td>1/2</td>
<td>7.8 g (est.)</td>
</tr>
<tr>
<td>4</td>
<td>W 9 (KW 4269)</td>
<td>Hematite</td>
<td>3.92 g</td>
<td>--</td>
<td>1/2</td>
<td>7.84 g</td>
</tr>
<tr>
<td>5</td>
<td>W 31 (KW 1854)</td>
<td>Diorite (?)</td>
<td>5.85 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.27 g (orig.)</td>
<td></td>
<td>1</td>
<td>7.27 g (orig.)</td>
</tr>
<tr>
<td>6</td>
<td>W 32 (KW 4424)</td>
<td>Bronze</td>
<td>5.63 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.47 g (est.)</td>
<td></td>
<td>1</td>
<td>7.47 g (est.)</td>
</tr>
<tr>
<td>7</td>
<td>W 33 (KW 804)</td>
<td>Hematite</td>
<td>7.69 g</td>
<td>--</td>
<td>1</td>
<td>7.69 g</td>
</tr>
<tr>
<td>8</td>
<td>W 34 (KW 2667)</td>
<td>Limonite/ Goethite</td>
<td>7.75 g</td>
<td>--</td>
<td>1</td>
<td>7.75 g</td>
</tr>
<tr>
<td>9</td>
<td>W 52 (KW 5738)</td>
<td>Hematite</td>
<td>14.28 g</td>
<td>--</td>
<td>2</td>
<td>7.14 g</td>
</tr>
<tr>
<td>10</td>
<td>W 61 (KW 323)</td>
<td>Hematite</td>
<td>22.02 g</td>
<td>--</td>
<td>3</td>
<td>7.34 g</td>
</tr>
<tr>
<td>11</td>
<td>W 91 (KW 4964)</td>
<td>Hematite</td>
<td>73.89 g</td>
<td>--</td>
<td>10</td>
<td>7.39 g</td>
</tr>
<tr>
<td>12</td>
<td>W 130 (KW 830)</td>
<td>Diorite (?)</td>
<td>7.632 ± 2 g</td>
<td>--</td>
<td>1000</td>
<td>7.63 g</td>
</tr>
</tbody>
</table>
Mean resultant average of intact weights 7.43 g
Mean resultant average of all weights 7.44 g
Mean resultant weighted average of intact weights 7.38 g
Mean resultant weighted average of all weights 7.39 g
(Note: Averages do not include fractional denominations and weight W 130 [KW 830])

The presence of the peyem, or the so-called Eblite or Paleoysrian standard (7.83 g at Ugarit) among the Uluburun sphendonoids with a unit mass of ca. 7.4 g, is difficult to prove, as the weight pieces that may be attributed to this standard show considerable variation in the range of their unit masses. Assuming our attributions are correct, however, we do seem to have a functional set of balance weights conforming to this standard that could have weighed up to about 20 units, or approximately 150 g, if all the pieces were used simultaneously. A 5-unit denomination, however, is missing. Such an element would normally have been included in a basic set of weights. If, on the other hand, all four 1-unit pieces belong to this set, then all integer denominations between 1 and 19 units may be generated, albeit in a somewhat cumbersome fashion in the absence of the 5-unit piece. This aspect in itself is sufficient to reveal that this standard was not used in everyday weighing transactions involving bulk merchandise. Moreover, the paucity of fractional balance weights in the set, assuming that not many pieces of the original set were overlooked during the excavation, indicates that the set was not employed frequently for commercial purposes. It may have been used, however, by an assayer who exchanged precious metals or performed conversions to other mass standards. With that, we find it difficult to explain the heaviest weight on the Uluburun shipwreck, W 130 (KW830) of 7,632 ± 2 g, which corresponds to 1,000 units of 7.6 g and may represent 20 minas or, more likely, 10 double minas. Fashioned of green diorite (?) in a highly stylized duck form, the piece is virtually useless as an element of a weight set, as there are no companion weights of sequentially smaller masses to provide a practical combination
of weights. It would be useful, however, if viewed as a reference standard against which certain commodities of predetermined quantities could be checked. This latter possibility is certainly in keeping with our assessment of the other weight pieces of this standard.

Of interest for the set are three rectangular or "bread-loaf-shaped" weights (W 9 [KW 4269], W 33 [KW 804], W 61 [KW 323]). Perhaps the shapes served as a reminder of the standard's antiquity. These shapes could also facilitate a set's identification and separation from others.

The third standard that appears to be present among the corpus of Uluburun sphendonoid weights is one that was commonly used in Mesopotamia. It is based on a unit in the vicinity of ca. 8.3 g; based on the examples found at Ras Shamra/Ugarit Courtois (1990: 122) gives the range of its unit as 8 g to 8.5 g. As with the previous standard (Table 10), the balance-weight pieces that may be attributed to the Mesopotamian standard are mostly of small denominations, with more than half representing the unit mass of the standard or fractions thereof. With its many fractional specimens and several multiples, the largest being 10 units, all the elements necessary for mensuration of masses of up to about 30 units (when all are used) are present. In this set we seem to have the following fractional and multiple units: 1/5, 1/4, 1/2, 2/3, 3/4, 1, 5, and 10. Curiously absent is a 2-unit denomination, which would have been normally incorporated in a weight set. Because the set's limited mass range would have essentially prohibited bulk mensuration of everyday merchandise, like the previous set this too probably was kept on the ship as an assayer's set for the weighing of precious metals, and perhaps also for the conversion of other mass standards. For the Mesopotamian mass standard of 8.3 g, we propose the following unit attributions and resultant unit masses (table 11).

Among the Uluburun sphendonoids are a few balance weights that confound our attempts to attribute them to one of the three mass standards presented above. It is possible that they are members of yet another standard or standards but they are
Table 11. Uluburun weight pieces of the sphenodonid group that appear to conform to a system with a standard unit mass of ca. 8.3 g, and their likely unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 2 (KW 1660)</td>
<td>Hematite</td>
<td>1.78 g</td>
<td>--</td>
<td>1/5</td>
<td>8.90 g</td>
</tr>
<tr>
<td>2</td>
<td>W 3 (KW 1596)</td>
<td>Steatite</td>
<td>2.07 g</td>
<td>--</td>
<td>1/4</td>
<td>8.28 g</td>
</tr>
<tr>
<td>3</td>
<td>W 10 (KW 1583)</td>
<td>Limonite</td>
<td>4.01 g</td>
<td>--</td>
<td>1/2</td>
<td>8.02 g</td>
</tr>
<tr>
<td>4</td>
<td>W 11 (KW 3164)</td>
<td>Hematite</td>
<td>4.01 g</td>
<td>--</td>
<td>1/2</td>
<td>8.02 g</td>
</tr>
<tr>
<td>5</td>
<td>W 12 (KW 503)</td>
<td>Bronze</td>
<td>3.21 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.07 g (est.)</td>
<td>--</td>
<td>1/2</td>
<td>8.14 g</td>
</tr>
<tr>
<td>6</td>
<td>W 14 (KW 228)</td>
<td>Ilmenite</td>
<td>4.25 g</td>
<td>--</td>
<td>1/2</td>
<td>8.50 g</td>
</tr>
<tr>
<td>7</td>
<td>W 15 (KW 2032)</td>
<td>Hematite</td>
<td>4.39 g</td>
<td>--</td>
<td>1/2</td>
<td>8.78 g</td>
</tr>
<tr>
<td>8</td>
<td>W 19 (KW 494)</td>
<td>Hematite</td>
<td>5.38 g</td>
<td>--</td>
<td>2/3</td>
<td>8.07 g</td>
</tr>
<tr>
<td>9</td>
<td>W 20 (KW 1425)</td>
<td>Hematite</td>
<td>5.51 g</td>
<td>--</td>
<td>2/3</td>
<td>8.27 g</td>
</tr>
<tr>
<td>10</td>
<td>W 35 (KW 1915)</td>
<td>Diorite (?)</td>
<td>8.01 g</td>
<td>--</td>
<td>1</td>
<td>8.01 g</td>
</tr>
<tr>
<td>11</td>
<td>W 36 (KW 2336)</td>
<td>Hematite/Goethite/Lead</td>
<td>8.02 g (-)</td>
<td>--</td>
<td>1</td>
<td>8.02 g (-)</td>
</tr>
<tr>
<td>12</td>
<td>W 37 (KW 2377)</td>
<td>Limonite</td>
<td>8.23 g</td>
<td>--</td>
<td>1</td>
<td>8.23 g</td>
</tr>
<tr>
<td>13</td>
<td>W 62 (KW 1771)</td>
<td>Bronze</td>
<td>18.69 g (-)</td>
<td>--</td>
<td>--</td>
<td>8.52 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25.56 g (est.)</td>
<td>--</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>W 63 (KW 4944)</td>
<td>Hematite</td>
<td>25.25 g (-)</td>
<td>--</td>
<td>--</td>
<td>8.65 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25.96 g (cal.)</td>
<td>--</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>W 76 (KW 4438)</td>
<td>Hematite</td>
<td>41.63 g</td>
<td>--</td>
<td>5</td>
<td>8.33 g</td>
</tr>
<tr>
<td>16</td>
<td>W 77 (KW 4214)</td>
<td>Bronze</td>
<td>42.21 g</td>
<td>--</td>
<td>5</td>
<td>8.44 g</td>
</tr>
<tr>
<td>17</td>
<td>W 78 (KW 564)</td>
<td>Bronze</td>
<td>37.83 g (-)</td>
<td>--</td>
<td>--</td>
<td>8.48 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>42.41 g (est.)</td>
<td>--</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>W 92 (KW 874)</td>
<td>Bronze</td>
<td>76.04 g (-)</td>
<td>--</td>
<td>10</td>
<td>8.21 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>82.09 g (est.)</td>
<td>--</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean resultant average of intact weights 8.25 g
Mean resultant average of all weights 8.32 g
Mean resultant weighted average of intact weights 8.34 g
Mean resultant weighted average of all weights 8.36 g
(Note: Averages do not include fractional denominations)

insufficient in number to constitute a fully functional set or sets. Partial sets are not
very useful in most mass mensuration procedures, but these pieces may have been kept
as reference weights for the purpose of converting different standards.

Five of these weights (W 47 [KW 462], W 48 [KW 803], W 51 [KW 4310], W
61 [KW 323], W 75 [KW 492]) possibly conform to the necef standard of ca. 10.5 g.
The three lightest weight pieces, probably representing the standard’s unit mass, are
somewhat on the heavy side. With some hesitation, we propose the following unit
attributions and resultant unit masses with regard to the necef system (table 12).

Table 12. Uluburun weight pieces of the sphenodontoid group that may conform to a
system with a standard unit mass of ca. 10.5 g, and their likely unit attributions and
resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 5 (KW 337)</td>
<td>Bronze</td>
<td>2.71 g (-)</td>
<td>I</td>
<td>--</td>
<td>10.47 g (est.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.49 g (est.)</td>
<td></td>
<td>1/3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>W 44 (KW 5739)</td>
<td>Ilmenite</td>
<td>10.45 g</td>
<td>--</td>
<td>1</td>
<td>10.45 g</td>
</tr>
<tr>
<td>3</td>
<td>W 45 (KW 3318)</td>
<td>Hematite</td>
<td>10.47 g</td>
<td>--</td>
<td>1</td>
<td>10.47 g</td>
</tr>
<tr>
<td>4</td>
<td>W 46 (KW 5143)</td>
<td>Ilmenite (?)/Bronze</td>
<td>10.61 g (-)</td>
<td>--</td>
<td>1</td>
<td>10.61 g (-)</td>
</tr>
<tr>
<td>5</td>
<td>W 47 (KW 462)</td>
<td>Limestone</td>
<td>10.68 g</td>
<td>--</td>
<td>1</td>
<td>10.68 g</td>
</tr>
<tr>
<td>6</td>
<td>W 48 (KW 803)</td>
<td>Steatite</td>
<td>10.75 g</td>
<td>--</td>
<td>1</td>
<td>10.75 g</td>
</tr>
<tr>
<td>7</td>
<td>W 50 (KW 921)</td>
<td>Hematite</td>
<td>10.92 g</td>
<td>--</td>
<td>1</td>
<td>10.92 g</td>
</tr>
<tr>
<td>8</td>
<td>W 51 (KW 4310)</td>
<td>Hematite</td>
<td>11.09 g</td>
<td>--</td>
<td>1</td>
<td>11.09 g</td>
</tr>
<tr>
<td>9</td>
<td>W 75 (KW 492)</td>
<td>Bronze</td>
<td>22.41 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30.05 g (est.)</td>
<td></td>
<td>3</td>
<td>10.02 g (est.)</td>
</tr>
</tbody>
</table>
Mean resultant average of intact weights 10.73 g
Mean resultant average of all weights 10.62 g
Mean resultant weighted average of intact weights 10.73 g
Mean resultant weighted average of all weights 10.50 g
(Note: Averages do not include fractional denominations)

It is noteworthy that the sphendonoid weights, like their domed counterparts, comprise identical denominations within the mass range common to both shapes. That is, sphendonoid fractional and multiple units of 1/2, 2/3, 1, 2, 3, 5, and 10 are common also to the Uluburun domed weights, as we shall see. Domed weights are also present in the higher denominations of 20, 30, 50 (1-mina), and 100 (2-mina) units, which are not found among the sphendonoids. Conversely, the sphendonoids occur in denominations of 1/6-, 1/3-, and perhaps 3/4-units, which probably were not incorporated into the domed sets.

The Domed Weights. The domed weights represent the smaller of the two major balance weight groups in the Uluburun assemblage. For the most part, they appear to conform to a single standard based on a unit mass of ca. 9.3, as we shall see below. Consequently, they are significantly easier to interpret than the sphendonoids. In the corpus of Uluburun weights, 41 of the 148 weights may be allotted to the domed group.

Marks appear on only two weights (W 120 [KW 3501], W 124 [KW 4165]), a mere 4.9%, and therefore do not appear to help reveal the unit mass(es) of the system(s) on which they are based. Both marks, which are of the same configuration, are incised on the bases of specimens made of the same type of stone, probably diorite, and almost certainly signify elements of the same weight set. On W 120 (KW 3501), a weight of 275.79 g representing 30 shekels of 9.19 g, the mark covers approximately a quarter of the weight’s base, while that on W 124 (KW 4165), a weight of 456.48 g representing 50 shekels of 9.13 g, is much smaller. The mark, consisting of two
straight, perpendicular incisions that meet but do not intersect, is not common on Near Eastern and Egyptian weights. Courtois (1984a: 80, 82) reports a 1-mina domed weight of gabbro from Pyla-Kokkinokremos on Cyprus (inv. No. 123; 463 g) that weighs 463 g. It has on its top surface two marks. The first, probably a Cypro-Minoan sign, is followed by a \( \vee \), which may indicate the mina unit. While this mark forms an acute angle rather than the 90\% angle seen on weight W 124 (KW 4165), its presence on a weight of almost the same 1-mina mass may be more than coincidence. Petrie (1926: 15), on the other hand, interprets a similar sign, read as \( \wedge \), on a stone weight from Egypt (no. 3594) as probably representing the unit 10, the balance weight on which it is incised thus being 10/3 of the qedet. While this similarity of marks on the Uluburun and Pyla-Kokkinokremos weights of nearly the same mass, and representing the mina norm, is striking, another Uluburun balance weight, W 120 (KW 3501), bears the same mark executed on a larger format. It weighs only 275.79 g and as such represents 30 shekels of 9.19 g. The meaning of the two Uluburun marks is clearly equivocal, but it is important to note that two 1-mina weights of nearly identical mass bear a similar mark. If we assume, at least for the larger weight, W 124 (KW 4165), that a mina of this standard weights 456.48 g, then we may derive the unit mass as 9.13 g, a somewhat lighter version of a Bronze Age standard well attested in Syria, Egypt, and on Cyprus (9.3 g). Accordingly, we propose the following unit attributions and resultant unit masses for the Uluburun domed weights (table 13).

As might be expected, the proposed attributions indicate the presence of a decimally factored system based on a unit mass in the vicinity of 9.3 g. Table 13 may be summarized in graphs (figs. 9 and 10) that plot the masses of the well-preserved domed weights against their predicted fractions and multiples of 9.3 g. Figure 9 shows weights in the range of 0 to 30 g, and figure 10 shows those from 30 g to 500 g. As always, each mark on the diagonals represents the mass of one balance weight. It is clear from the above tables and graphs that the Uluburun domed weights form coherent clusters for all predicted integer multiples of the standard based on a unit
Table 13. The Uluburun domed weights with their predicted unit attributions and resultant unit masses, based on a unit mass of 9.3 g.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 13 (KW 4466)</td>
<td>Hematite</td>
<td>4.11 g</td>
<td></td>
<td>1/2</td>
<td>8.22 g</td>
</tr>
<tr>
<td>2</td>
<td>W 16 (Lot 918)</td>
<td>Bronze</td>
<td>1.07 g (-)</td>
<td>4.57 g (est.)</td>
<td>--</td>
<td>9.14 g (est.)</td>
</tr>
<tr>
<td>3</td>
<td>W 24 (Lot 1796)</td>
<td>Hematite</td>
<td>6.12 g</td>
<td></td>
<td></td>
<td>9.18 g</td>
</tr>
<tr>
<td>4</td>
<td>W 26 (KW 768)</td>
<td>Bronze</td>
<td>1.10 g (-)</td>
<td>6.31 g (est.)</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>W 28 (KW 4364)</td>
<td>Hematite</td>
<td>6.62 g</td>
<td></td>
<td>2/3</td>
<td>9.93 g</td>
</tr>
<tr>
<td>6</td>
<td>W 38 (KW 4100)</td>
<td>Stone</td>
<td>8.38 g</td>
<td></td>
<td>1 (?)</td>
<td>8.38 g</td>
</tr>
<tr>
<td>7</td>
<td>W 39 (KW 3836)</td>
<td>Bronze</td>
<td>8.72 g (-)</td>
<td></td>
<td></td>
<td>8.72 g (-)</td>
</tr>
<tr>
<td>8</td>
<td>W 43 (KW 787)</td>
<td>Hematite</td>
<td>10.37 g</td>
<td></td>
<td></td>
<td>10.37 g</td>
</tr>
<tr>
<td>9</td>
<td>W 49 (KW 5130)</td>
<td>Limestone</td>
<td>10.89 g</td>
<td></td>
<td></td>
<td>10.89 g</td>
</tr>
<tr>
<td>10</td>
<td>W 54 (KW 3834)</td>
<td>Ilmenite</td>
<td>18.70 g</td>
<td></td>
<td>2</td>
<td>9.35 g</td>
</tr>
<tr>
<td>11</td>
<td>W 57 (KW 2762)</td>
<td>Limestone</td>
<td>18.70 g (-)</td>
<td>18.83 g (cal.)</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>W 59 (KW 4272)</td>
<td>Hematite</td>
<td>19.62 g</td>
<td></td>
<td>2</td>
<td>9.81 g</td>
</tr>
<tr>
<td>13</td>
<td>W 64 (KW 521)</td>
<td>Limestone</td>
<td>27.28 g</td>
<td></td>
<td>3</td>
<td>9.09 g</td>
</tr>
<tr>
<td>14</td>
<td>W 66 (KW 4369)</td>
<td>Limestone</td>
<td>27.90 g</td>
<td></td>
<td>3</td>
<td>9.30 g</td>
</tr>
<tr>
<td>15</td>
<td>W 67 (KW 3972)</td>
<td>Limestone</td>
<td>27.93 g</td>
<td></td>
<td>3</td>
<td>9.31 g</td>
</tr>
<tr>
<td>16</td>
<td>W 73 (KW 325)</td>
<td>Hematite</td>
<td>28.94 g</td>
<td></td>
<td>3</td>
<td>9.65 g</td>
</tr>
<tr>
<td>17</td>
<td>W 87 (KW 4547)</td>
<td>Diorite (?)</td>
<td>46.51 g</td>
<td></td>
<td>5</td>
<td>9.30 g</td>
</tr>
<tr>
<td>18</td>
<td>W 88 (KW 4368)</td>
<td>Hematite/Ilmenite (?)</td>
<td>46.79 g</td>
<td></td>
<td>5</td>
<td>9.36 g</td>
</tr>
<tr>
<td>19</td>
<td>W 95 (KW 3978)</td>
<td>Marl (?)</td>
<td>90.08 g</td>
<td></td>
<td>10</td>
<td>9.01 g</td>
</tr>
<tr>
<td>20</td>
<td>W 97 (KW 5151)</td>
<td>Magnetite</td>
<td>91.37 g</td>
<td></td>
<td>10</td>
<td>9.14 g</td>
</tr>
<tr>
<td>21</td>
<td>W 98 (KW 863)</td>
<td>Limonite</td>
<td>91.61 g</td>
<td></td>
<td>10</td>
<td>9.16 g</td>
</tr>
<tr>
<td>22</td>
<td>W 105 (KW 153)</td>
<td>Hematite</td>
<td>93.03 g</td>
<td></td>
<td>10</td>
<td>9.30 g</td>
</tr>
<tr>
<td>23</td>
<td>W 106 (KW 774)</td>
<td>Hematite</td>
<td>93.17 g</td>
<td></td>
<td>10</td>
<td>9.32 g</td>
</tr>
</tbody>
</table>
Table 13, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>W 110 (KW 3840)</td>
<td>Bronze</td>
<td>160.49 g (-)</td>
<td>—</td>
<td>20 (7)</td>
<td>(7)</td>
</tr>
<tr>
<td>25</td>
<td>W 112 (KW 1917)</td>
<td>Diorite (?)</td>
<td>182.30 g (-)</td>
<td>—</td>
<td>—</td>
<td>9.22 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>183.25 g (cal.)</td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>W 113 (KW 2696)</td>
<td>Hematite</td>
<td>184.33 g</td>
<td>—</td>
<td>20</td>
<td>9.25 g</td>
</tr>
<tr>
<td>27</td>
<td>W 114 (KW 3233)</td>
<td>Hematite</td>
<td>185.04 g</td>
<td>—</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>W 115 (KW 5737)</td>
<td>Hematite</td>
<td>183.83 g (-)</td>
<td>—</td>
<td>—</td>
<td>9.26 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>185.24 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>W 116 (KW 857)</td>
<td>Hematite</td>
<td>185.64 g</td>
<td>—</td>
<td>20</td>
<td>9.28 g</td>
</tr>
<tr>
<td>30</td>
<td>W 117 (KW 3279)</td>
<td>Hematite</td>
<td>185.68 g</td>
<td>—</td>
<td>20</td>
<td>9.28 g</td>
</tr>
<tr>
<td>31</td>
<td>W 118 (KW 3195)</td>
<td>Hematite</td>
<td>186.74 g</td>
<td>—</td>
<td>20</td>
<td>9.34 g</td>
</tr>
<tr>
<td>32</td>
<td>W 119 (KW 3343)</td>
<td>Hematite</td>
<td>187.43 g</td>
<td>—</td>
<td>20</td>
<td>9.37 g</td>
</tr>
<tr>
<td>33</td>
<td>W 120 (KW 3501)</td>
<td>Diorite</td>
<td>275.79 g</td>
<td>L</td>
<td>30</td>
<td>9.19 g</td>
</tr>
<tr>
<td>34</td>
<td>W 121 (KW 578)</td>
<td>Hematite</td>
<td>278.61 g</td>
<td>—</td>
<td>30</td>
<td>9.29 g</td>
</tr>
<tr>
<td>35</td>
<td>W 122 (KW 571)</td>
<td>Serpentine</td>
<td>278.63 g</td>
<td>—</td>
<td>30</td>
<td>9.29 g</td>
</tr>
<tr>
<td>36</td>
<td>W 123 (KW 3099)</td>
<td>Limestone</td>
<td>323.57 g (-)</td>
<td>—</td>
<td>50 (7)</td>
<td>(7)</td>
</tr>
<tr>
<td>37</td>
<td>W 124 (KW 4165)</td>
<td>Diorite</td>
<td>456.48 g</td>
<td>L</td>
<td>50</td>
<td>9.13 g</td>
</tr>
<tr>
<td>38</td>
<td>W 125 (KW 710)</td>
<td>Hematite</td>
<td>458.54 g</td>
<td>—</td>
<td>50</td>
<td>9.17 g</td>
</tr>
<tr>
<td>39</td>
<td>W 126 (KW 382)</td>
<td>Diorite (?)</td>
<td>460.32 g (-)</td>
<td>—</td>
<td>—</td>
<td>9.25 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>462.40 g (cal.)</td>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>W 127 (KW 477)</td>
<td>Hematite</td>
<td>916.7 g</td>
<td>—</td>
<td>100</td>
<td>9.17 g</td>
</tr>
<tr>
<td>41</td>
<td>W 128 (KW 1511)</td>
<td>Hematite</td>
<td>923.2 g (-)</td>
<td>—</td>
<td>—</td>
<td>9.26 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>925.6 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean resultant average of intact weights 9.34 g
Mean resultant average of all weights 9.32 g
Mean resultant weighted average of intact weights 9.23 g
Mean resultant weighted average of all weights 9.23 g

(Note: Averages do not include fractional denominations)
Fig. 9. Proposed fractions and multiple attributions of the standard unit mass of ca. 9.3 g evident in the Uluburun domed weights in the range of 0 g to 30 g.
Fig. 10. Proposed multiples attributions of the standard unit mass of ca. 9.3 g evident in the Uluburun domed weights in the range of 30 g to 500 g. Two 100-unit weights of 916.7 g (W 127 [KW 477]) and 925.6 g (cal.) (W 128 [KW 1511]), and damaged weights W 110 (KW 3840) and W 123 (KW 3099) are not shown.
mass of ca. 9.3 g. But, at the unit level, and to some extent in the fractional range, we encounter some difficulty. In fact it is surprising that for these weight pieces, which so closely approximate the masses of their predicted multiple units, we find unit mass values that far exceed the limits acceptable for the standard. With the possible exception of bronze weight W 39 KW 3836, which is underweight at 8.72 g and may have been closer to 9.3 g originally, no weight specimen is within one standard deviation (ca. 67%) of the average of ca. 9.3 g revealed by our quantal search. This is a peculiarity that we are unable to explain at present. It is known that ancient balances were less accurate when weighing lighter masses and, consequently, deviations from the norm are expected to be greater with the lighter weight specimens. But this inherent problem with balances cannot alone explain the great latitude represented by domed weights W 38 [KW 4100], W 49 [KW 5130], and (W 43 [KW 787]), which are presumably 1-unit mass pieces. This is especially true when one considers that fractional weights of the same group, which, while somewhat lighter than the unit mass determined for this standard, are certainly within acceptable limits of deviation from the mean unit mass. It is possible, on the other hand, that the two heavier weight pieces (W 49 [KW 5130], W 43 [KW 787]) represent the necef standard, with a unit mass of ca. 10.5 g. If such were the case, however, it would then seem odd that the 40 domed balance weights in our group, which represent nine different multiple units and two fractional units, all conform fairly closely to a standard of ca. 9.3 g, as determined both analytically and intuitively, while the unit pieces are those of another standard. If the necef standard was truly represented, one would expect to find other multiple units of that standard. For all practical purposes, therefore, these three weight pieces will be treated as representing over- and underweight unit masses of ca. 9.3 g.

What is clear from the multiple-unit attributions represented by the domed balance weights is that the unit mass of the system corresponds to a shekel of ca. 9.3 g. At the heavier end of the multiple-unit spectrum we have four 50-unit weight
pieces (W 123 [KW 3099], W 124 [KW 4165], W 125 [KW 710], W 126 [KW 382])
that must correspond to the Ugaritic/Syrian mina of 50 shekels. The two 100-unit
weight pieces in the group (W 127 [KW 477], W 128 [KW 1511]), then, are 2-mina or
double-mina weights of 100 shekels each. But, this is the extent of the mina-standard
group, as masses smaller than the mina do not appear to be derived through division of
the double mina. This is clearly suggested by the 30-unit weight pieces in the
assemblage. In other words, the masses of balance weights W 120 (KW 3501), W 121
(KW 578), and W 122 (KW 571), do not represent 1/3 of the double mina, but 30
shekels. This also holds true for the 3-unit pieces (W 64 [KW 521], W 66 [KW
4369], W 67 [KW 3972], W 73 [KW 325]), which are too light to be 1/30 of the
double mina. Similarly, neither 25 units, representing 1/2 mina, nor 12.5 units
corresponding to 1/4 mina, are found. We have on the Uluburun shipwreck, therefore,
a series of balance weights whose decimally configured shekel system is based on
fractions and multiples of a unit mass of ca. 9.3 g. The theoretical masses for the
system’s fractional and multiple units, as derived from a unit of 9.3 g, are given in
table 14.

It is apparent from the greater number of heavier weight pieces that the
Uluburun domed weights were used primarily in transactions involving heavy and,
probably, bulk or coarse merchandise. In fact, more than half of the balance weights in
this group weigh 10 units or more, with only 4 of the 40 pieces representing fractional
units. Of the four fractional pieces, W 16 (Lot 918) is of bronze and only about two-
thirds complete and, as such, is not attributable to any fractional unit with certainty;
we cannot even be certain that this incomplete object represents a balance weight. If
we consider its estimated mass after restoration with plasticine, however, it seems
likely that it represents a 1/2-unit piece, albeit just marginally on the light side. The
remaining three fractional balance weights, W 13 (KW 4466), W 24 (Lot 1796), and
W 28 (KW 4364) represent 1/2-, 2/3-, and 2/3-units, respectively. Of these, W 24
(Lot 1796) appears to be a piece of hematite chipped from a much larger balance
Table 14. Theoretical masses for fractional and multiple units based on a standard unit mass of 9.3 g, and the probable number of examples among the Uluburun domed weights.

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Mass</th>
<th>No. of Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/3 unit</td>
<td>3.10 g</td>
<td>1 (?)</td>
</tr>
<tr>
<td>1/2 unit</td>
<td>4.65 g</td>
<td>1</td>
</tr>
<tr>
<td>2/3 unit</td>
<td>6.2 g</td>
<td>2</td>
</tr>
<tr>
<td>1 unit</td>
<td>9.3 g</td>
<td>4</td>
</tr>
<tr>
<td>2 units</td>
<td>18.6 g</td>
<td>3</td>
</tr>
<tr>
<td>3 units</td>
<td>27.9 g</td>
<td>4</td>
</tr>
<tr>
<td>5 units</td>
<td>46.5 g</td>
<td>2</td>
</tr>
<tr>
<td>10 units</td>
<td>93.0 g</td>
<td>5</td>
</tr>
<tr>
<td>20 units</td>
<td>186.0 g</td>
<td>9</td>
</tr>
<tr>
<td>30 units</td>
<td>279.0 g</td>
<td>3</td>
</tr>
<tr>
<td>50 units (1 mina)</td>
<td>465.0 g</td>
<td>4</td>
</tr>
<tr>
<td>100 units (2 mina)</td>
<td>930.0 g</td>
<td>2</td>
</tr>
</tbody>
</table>

weight. The worn features on its fractured side, which originally joined its parent weight, reveal that the break is not recent and that the piece probably was not simply discarded after breaking, but used in antiquity as a fractional weight piece.

During the excavation of the Uluburun shipwreck, many pebbles were recovered. Most are naturally beach or river polished, but a few have been specifically modified by grinding. The latter, in view of their shapes, probably were intended for use as beads, pendants, or the like, but some could have served as balance weights. They have yet to be studied, but one such pebble (Lot 9367), presumably unmodified in any way, selected for scrutiny only because of its secure context and strikingly uniform shape and color, weighs 2.89 g and may represent a somewhat underweight 1/3-shekel of 8.67 g. But, it may just as likely represent a somewhat heavy 1/3-shekel
of an 8.3-g norm, although there do not appear to be higher multiples of this standard among the domed group. It is possible that this and other pebbles were a merchant’s personalized fractional weights chosen specifically for their natural geometric shapes and close approximations of the desired masses.

Setting these scanty, troublesome, fractional weights aside and reviewing only the multiple units, it seems that at least three, and possibly as many as four, separate sets of domed weights were carried on board the Uluburun ship. The discernment of these sets is not necessarily easy, however, as each set may comprise a different quantity of like denominations as well as a different mix of multiples. Also, certain units present in one set may be absent in another. The simplest explanation for such variation could be that some of the balance weights are still on the seabed at Uluburun. While this could be true, that the entire site was thoroughly excavated down to bedrock and that many other smaller, fractional units of the sphendonoid group were recovered makes it difficult to explain in this way the absence of all the missing pieces. Perhaps some were lost in antiquity during use and replaced with pieces of sphendonoid shape. If so, it would be virtually impossible to identify these surrogate sphendonoids.

Within the category of domed balance weights from Uluburun are two basic shapes. These have been termed “domed” and “dome-top” by Petrie (1926: 5), who devoted considerable energy to the morphology of balance weights and attempted to date them based on their shapes. The “domed” weights are typical in that their curving sides spring upward directly from their flat bases; they have no flat sides. To be included in this type are all weights commonly called “sugar-loaf,” “truncated-sphere,” and “flattened-sphere” weights. The “dome-top” balance weights, on the other hand, include all weights with straight sides that may be perpendicular to the weight’s base or taper in or out slightly from it to join its dome top. Their dome-tops also show considerable variation, with the typical specimens, commonly called “cupcake,” exhibiting well-formed domes while others have nearly flat tops. Both the
Table 15. The proposed Uluburun domed weight sets.

<table>
<thead>
<tr>
<th>Units</th>
<th>1/3</th>
<th>1/2</th>
<th>2/3</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domed</td>
<td></td>
<td></td>
<td></td>
<td>W 49</td>
<td>W 57</td>
<td>W 66</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(KW 5130)</td>
<td>(KW 2762)</td>
<td>(KW 4369)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W 64</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(KW 521)</td>
</tr>
<tr>
<td>Dometopped</td>
<td>--</td>
<td>W 13</td>
<td>W 24</td>
<td>W 38</td>
<td>W 54</td>
<td>W 68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(KW 4466)</td>
<td>(Lot 1796)</td>
<td>(KW 4100)</td>
<td>(KW 3834)</td>
<td>(KW 1168)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat-topped</td>
<td>--</td>
<td>--</td>
<td>W 28</td>
<td>W 39</td>
<td>W 59</td>
<td>W 67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(KW 4364)</td>
<td>(KW 3836)</td>
<td>(KW 4272)</td>
<td>(KW 3972)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domed</td>
<td>W 87</td>
<td>W 95</td>
<td>W 112</td>
<td>W 120</td>
<td>W 124</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(KW 4547)</td>
<td>(KW 3978)</td>
<td>(KW 1917)</td>
<td>(KW 3501)</td>
<td>(KW 4165)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>W 98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(KW 863)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dometopped</td>
<td>W 88</td>
<td>W 97</td>
<td>W 117</td>
<td>W 122</td>
<td>W 125</td>
<td>W 127</td>
</tr>
<tr>
<td></td>
<td>(KW 4368)</td>
<td>(KW 5151)</td>
<td>(KW 3279)</td>
<td>(KW 571)</td>
<td>(KW 710)</td>
<td>(KW 477)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 110</td>
<td>W 122</td>
<td>W 125</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(KW 3840)</td>
<td>(KW 571)</td>
<td>(KW 710)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 116</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(KW 857)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat-topped</td>
<td>--</td>
<td>W 105</td>
<td>W 118</td>
<td>W 121</td>
<td>W 126</td>
<td>W 128</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(KW 153)</td>
<td>(KW 3195)</td>
<td>(KW 578)</td>
<td>(KW 382)</td>
<td>(KW 1511)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W 106</td>
<td>W 119</td>
<td>W 121</td>
<td>W 123</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(KW 774)</td>
<td>(KW 3343)</td>
<td>(KW 578)</td>
<td>(KW 3099)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 113</td>
<td>W 121</td>
<td>W 123</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(KW 2696)</td>
<td>(KW 578)</td>
<td>(KW 3099)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 114</td>
<td>W 121</td>
<td>W 123</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(KW 3233)</td>
<td>(KW 578)</td>
<td>(KW 3099)</td>
<td></td>
</tr>
</tbody>
</table>
domed and dome-top types are found among the Uluburun weights, the latter making up the majority of the domed group. Nearly all of the 40 domed balance weights from Uluburun may be assigned to these types without great difficulty, but a few pieces are more problematic, and we cannot be certain of their attributions. We therefore propose for the Uluburun domed weights the three sets detailed in table 15.

The only major weight missing from the sets appears to be a 5-unit piece from the flat-topped domes, but other possible missing pieces include second 3-unit and 10-unit pieces from the dome-topped set, perhaps a second 20-unit piece from the domed set, and possibly a 100-unit (2-mina) piece from the same set. Note also that the dome-topped set includes three 20-unit pieces, the flat-topped domes four, one and two too many, respectively, even though these pieces have been assigned to their proper shape groups. But perhaps one belongs to the domed set, which would complete the set except for a 100-unit piece, which may not have been originally included at all.

With the possible exception of the fractional denominations, therefore, we have shown that all of the Uluburun domed weights may be assigned without difficulty to one of three weight sets based on morphological considerations alone. Moreover, except for possibly a few fractional denominations and a 5-unit piece, along with perhaps one or two more missing pieces at most, all three sets are complete. This may be taken as further corroboration of our initial premise, that the Uluburun ship almost certainly sank with all of its cargo and objects and that thorough excavation of the site has yielded virtually all of the balance weights originally aboard ship.

*The Aegean Standard.* The great majority of weights from the Aegean are disk-shaped and cast in lead, although some stone disk-shaped weights have also been recovered (Petruso 1992: 3). The disk shape was chosen probably because it is the simplest form in which lead can be poured, in addition to being one of the shapes that is most resistant to chipping. Disk weights also facilitate stacking (Petruso 1992: 3).
In the corpus of balance weights from Uluburun, eight objects are cataloged as lead-disk weights (table 16).

Table 16. The lead-disk weights from Uluburun.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 60 (KW 788)</td>
<td>19.88 g (-)</td>
</tr>
<tr>
<td>2</td>
<td>W 68 (KW 1168)</td>
<td>27.98 g (-)</td>
</tr>
<tr>
<td>3</td>
<td>W 79 (KW 487)</td>
<td>42.62 g (-)</td>
</tr>
<tr>
<td>4</td>
<td>W 93 (KW 1171)</td>
<td>85.49 g (-)</td>
</tr>
<tr>
<td>5</td>
<td>W 108 (KW 459)</td>
<td>139.51 g</td>
</tr>
<tr>
<td>6</td>
<td>W 109 (KW 298)</td>
<td>155.48 g (-)</td>
</tr>
<tr>
<td>7</td>
<td>W 111 (KW 1979)</td>
<td>172.05 g (-)</td>
</tr>
<tr>
<td>8</td>
<td>W 129 (KW 849)</td>
<td>2,483 ± 2 g (-)</td>
</tr>
</tbody>
</table>

Of these eight lead weights, three are flat, pierced disks, one is thin and rectangular, two are domed, and two are cylindrical. Although several of these pieces appear to be in a fairly good state of preservation, others are damaged and severely underweight. Even for the seemingly intact weights, however, it should be remembered that they are of metal and therefore subject to mass alteration through oxidation or metal leaching during prolonged submersion in the sea. For practical purposes, then, all eight weights should be somewhat lighter than originally intended and their attribution to specific mass standards and denominations is rather uncertain.

The three disk-shaped weights (W 108 [KW 459], W 109 [KW 298], W 111 [KW 1979]) are pierced through at their centers with tapered holes. Because such a modification does not appear to serve any utilitarian purpose in a pan-balance weight, at least in the case of Aegean weights, Petruso (1992: 4) generally rejects or only provisionally accepts pierced objects as balance weights. Indeed it is possible that
these three disks served another purpose. The circular shape and tapered hole suggest use as a spindle-whorl. This interpretation may find some support in the shape of the objects' surfaces: slightly convex on one side and concave on the other. Moreover, W 109 (KW 298) exhibits on its convex surface crudely incised curvilinear lines that radiate from the piece's central hole toward its periphery. These curvilinear lines suggest a rotary motion and also call to mind that of a spindle-whorl. Nor do the masses of these three lead disks seem to correspond neatly to the denominations of the standard they presumably represent. In the case of W 111 (KW 1979) this difficulty may be due partly to its poor preservation, the two other lead disks are relatively well preserved, though surely somewhat underweight. When the pierced, circular shape of these objects is considered, along with the difficulty of attributing them to known standards, it seems more probable that they are indeed spindle-whorls, for which they are admirably suited. On the other hand, the Uluburun ship yielded a few spindle-whorls of stone in the classic conical design. One must wonder, then, why there would have been spindle-whorls of different shapes and materials fulfilling the same function. A similar lead disk of about the same size, found at Hala Sultan Tekke in Cyprus, however, has been referred to as a "round weight" (Fischer 1980: 151-52, figs. 11-12).

Let us now consider the masses of these pierced disks and search for the standards and denominations they most likely represent. W 109 (KW 298) weighs 155.47 g (-). A few very small chips are evident around the disk's periphery, but for the most part its current mass probably approximates its original mass closely. W 108 (KW 459), weighing 139.51 g, is the lightest, but the best preserved, of the three disks. W 111 (KW 1979), on the other hand, is the heaviest, but badly damaged from corrosion, with significant loss of metal due to exfoliation from its periphery. Its mass of 172.05 g (-), therefore, is significantly underweight. Possible unit attributions and resultant unit masses for these disks are shown in table 17.
Table 17. Possible unit attributions and resultant unit masses for the three pierced lead disks from Uluburun.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Mass</th>
<th>Unit Attributions and Resultant Unit Mass</th>
</tr>
</thead>
</table>
| W 108 (KW 459) | 139.51 g | 15 units of 9.3 g  
|                |         | 2 units of 69.8 g (Aegean)  
|                |         | 2-1/2 units of 55.8 g (Aegean)                                                                       |
| W 109 (KW 298) | 155.48 g (-) | 20 units of 7.8 g (peyem)  
|                |         | 15 units of 10.4 g (necef)  
|                |         | 3 units of 52 g (Aegean)  
|                |         | 2-1/2 units of 62.2 g (Aegean)                                                                       |
| W 111 (KW 1979)| 172.05 g (-) | 20 units of 9 g (Ugaritic)  
|                |         | 3 units of 60 g (Aegean)                                                                               |

The attribution of the disks to the Aegean standard of ca. 61 g is not convincing. W 108 (KW 459) at 2 units of 69.8 g or 2-1/2 units of 55.8 g gives very high and very low resultant unit masses, respectively. In Petruso’s (1992: 78-82) catalog of 218 balance weights from the Aegean, not one has a resultant unit mass as high as 69.8 g. On the other hand, while the resultant unit mass of 55.8 g for 2-1/2 units is somewhat low, Petruso’s list includes two balance weights with masses lower than this value, even though there are no 2-1/2-unit pieces in his list. Balance weight W 109 (KW 298) may correspond to 3 units of 52 g or 2-1/2 units of 62.2 g. These resultant unit masses are extremely low in the first instance, and unlikely in the second because of the absence of 2-1/2-unit pieces elsewhere in the Aegean. W 111 (KW 1979) may correspond to 3 units of 60 g but its poor condition makes any attribution tentative. Of the three pierced disks it is the most likely to represent 3 units of the Aegean standard, but because W 109 (KW 298) and W 108 (KW 459) are not likely members of that norm, the conformity of W 111 (KW 1979) to 3 units of the standard may only be coincidental. Attributions of these pierced lead disks to other known standards produce equally unlikely, and mixed, results. W 108 (KW 459) may
correspond to 15 units of 9.3 g and W 111 (KW 1979) to 20 units of a light Ugaritic/Syrian shekel of ca. 9 g. However, 15-unit denominations are rare, or non-existent, in the corpus of weights attributable to a 9.3-g system, and the poor condition of W 111 (KW 1979) makes its attribution to a standard of ca. 9 g most questionable. We should remember also that W 111 (KW 1979) is the most likely representative of the Aegean system. Balance weight W 109 (KW 298) does not correspond to any likely multiple unit of this system, but its other possible attributions include 20 units of ca. 7.8 g in the peyem standard (Paleosyrian or Eblite) and 15 units of 10.4 g in the necef standard. The three pierced lead disks from Uluburun, therefore, do not conform to the same standards. Their attribution to a variety of possible standards in all likelihood further precludes their confident identification as balance weights.

The fourth lead “disk” from Uluburun (W 60 [KW 788]), not pierced, is quite possibly a weight of the Aegean standard, on the other hand. With a mass of 19.88 g (-), it may, in fact, correspond to 1/3 of a unit of 59.64 g (-). Petruso (1992: 78) lists six disk-shaped balance weights, two of stone and four of lead, ranging in mass from 19.4 g to 20.35 g. These pieces appear in table 18.

Lead weight W 60 (KW 788) is covered uniformly with a thin, sturdy corrosion layer that, for the most part, preserves some surface detail, most notably three pairs of small, peculiar, seemingly antithetic triangular “dents” or marks on one surface. These are not very distinct and their microscopic examination has failed to reveal whether they are intentional or accidental. Approximately the same number of similar marks also appear on the reverse face. Although it is difficult to establish the precise number of triangles on this weight, the three evident pairs of antithetical triangles do not seem to be related to the mass of the piece.

Three lead disks from Ayia Irini (Keos) are also incised with antithetic triangles (table 19). Petruso (1992: 28-29) interprets them as possible indicators of pieces belonging to one and the same system but in a decimal rather than binary series,
Table 18. Aegean disk weights in the mass range of 19.4 g to 20.35 g, as listed by Petruso.

<table>
<thead>
<tr>
<th>No.</th>
<th>Provenience</th>
<th>Marks</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
<th>Date</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>Knossos</td>
<td>.</td>
<td>19.4 g</td>
<td>1/3</td>
<td>58.2 g</td>
<td>--</td>
<td>Stone</td>
</tr>
<tr>
<td>74</td>
<td>Mochlos</td>
<td>...+</td>
<td>19.4 g</td>
<td>1/3</td>
<td>58.2 g</td>
<td>--</td>
<td>Lead</td>
</tr>
<tr>
<td>63</td>
<td>Knossos</td>
<td>+</td>
<td>19.82 g</td>
<td>--</td>
<td>--</td>
<td>Surface</td>
<td>Lead</td>
</tr>
<tr>
<td>92</td>
<td>Akrotiri</td>
<td>Δ</td>
<td>20.2 g</td>
<td>1/3</td>
<td>60.6 g</td>
<td>LMI</td>
<td>Stone</td>
</tr>
<tr>
<td>8</td>
<td>Ayia Irini</td>
<td>Δ1</td>
<td>20.25 g</td>
<td>1/3</td>
<td>60.8 g</td>
<td>LMIA-IB</td>
<td>Lead</td>
</tr>
<tr>
<td>9</td>
<td>Ayia Irini</td>
<td>.</td>
<td>20.35 g</td>
<td>1/3</td>
<td>61.1 g</td>
<td>LMIB</td>
<td>Lead</td>
</tr>
</tbody>
</table>

In which the double mina was the actual standard. In other words, the marked pieces in the Ayia Irini assemblage hint at the presence of a decimal system with a unit mass in the vicinity of 61 g. In a binary system the unit mass of ca. 61 g could have been easily and precisely generated on a double-pan balance by successively halving the double mina attested in Linear B tablets. After the unit mass of ca. 61 g had been reached in this fashion, any needed non-binary multiple, or in this case, decimal multiple, could have been generated (table 20). Petruso suggests that such a procedure may have been the purpose of lead disks bearing antithetic triangles (table 19). This interpretation could also help explain attributions to the decimal system of other unmarked lead disks, which otherwise do not fit into the general scheme of binary multiples of ca. 61 g. Accordingly, two weights from Ayia Irini, one bearing two pairs of antithetic triangles and weighing 53.3 g, the other displaying only a single pair of triangles and weighing 97.7 g, have been attributed to 1/20 and 1/10 of a double mina, respectively. If W 60 (KW 788) from Uluburun, at 19.88 g (-), is to be considered a decimaly generated weight of the double-mina standard, it should represent either 1/40 of a double mina of 795 g, which is far lighter than the calculated 988 g for the double mina, or 1/50 of a double mina of 994 g, a slightly heavier but
much closer value. In either case, we would expect to see four or five pairs of antithetic triangles, respectively, and not the three pairs that we see on W 60 (KW 788). Four unattributed lead disks listed by Petruso (1992: 78), which range in mass from 22.05 g to 24.3 g, may be 1/40-double-mina balance weight pieces corresponding to a calculated mass of 24.72 g, based on the double mina of 988.8 g. The meaning of these marks on W 60 (KW 788), whether deliberate or accidental, therefore, evades us at present. It is also possible, of course, that its mass simply corresponds to 1/3 of a unit of ca. 61 g.

Table 19. Double-mina fractional denominations with antithetical triangles, as listed by Petruso.

<table>
<thead>
<tr>
<th>No.</th>
<th>Marks</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass (Double Mina)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>&lt;&gt; &lt;&gt;</td>
<td>53.3 g</td>
<td>1/20 double mina (?)</td>
<td>1,066.0 g</td>
</tr>
<tr>
<td>47</td>
<td>&lt;&gt;</td>
<td>97.7 g</td>
<td>1/10 double mina</td>
<td>977.0 g</td>
</tr>
<tr>
<td>55</td>
<td>&lt;&gt; &lt;&gt;</td>
<td>1,158.8 g</td>
<td>12/10 double mina (?)</td>
<td>965.7 g</td>
</tr>
</tbody>
</table>

Three of the four remaining lead weights from Uluburun: W 68 (KW 1168), W 79 (KW 487), and W 93 (KW 1171), appear to correspond approximately to the following ratios of 1:2:4. While W 79 (KW 487) and W 93 (KW 1171) have the typical domed shapes of the stone and hematite weights from the Uluburun shipwreck that conform to a standard of ca. 9.3 g, they do not seem to be comfortable members of that system. On the other hand, they could be 5 units of 8.52 g and 10 units of 8.55 g of the Mesopotamian system. W 68 (KW 1168) is cylindrical in shape, and may be a 3 unit specimen of 9.33 g. If these weights are members of the Aegean system, then they may correspond to 1/3, 2/3 and 3/2 units of ca. 60 g as summarized in table 21.
Table 20. Calculated multiples of the Ayia Irini double mina.

<table>
<thead>
<tr>
<th>Denomination</th>
<th>Mass</th>
<th>Denomination</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 unit</td>
<td>15.45 g</td>
<td>1/50 double mina</td>
<td>19.78 g</td>
</tr>
<tr>
<td>1/3 unit</td>
<td>20.6 g</td>
<td>1/40 double mina</td>
<td>24.72 g</td>
</tr>
<tr>
<td>1/2 unit</td>
<td>30.9 g</td>
<td>1/30 double mina</td>
<td>32.96 g</td>
</tr>
<tr>
<td>2/3 unit</td>
<td>41.2 g</td>
<td>1/20 double mina</td>
<td>49.44 g</td>
</tr>
<tr>
<td>1 unit</td>
<td>61.8 g</td>
<td>1/10 double mina</td>
<td>98.8 g</td>
</tr>
<tr>
<td>3/2 units</td>
<td>92.7 g</td>
<td>2/10 double mina</td>
<td>197.6 g</td>
</tr>
<tr>
<td>2 units</td>
<td>123.6 g</td>
<td>3/10 double mina</td>
<td>296.4 g</td>
</tr>
<tr>
<td>6 units</td>
<td>370.8 g</td>
<td>4/10 double mina</td>
<td>395.5 g</td>
</tr>
<tr>
<td>8 units</td>
<td>494.4 g</td>
<td>1 double mina</td>
<td>988.8 g</td>
</tr>
<tr>
<td>10 units</td>
<td>618.0 g</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>16 units</td>
<td>988.8 g</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 21. Possible attributions of lead weights from Uluburun to the Aegean standard and their resulting unit masses.

<table>
<thead>
<tr>
<th>Cat. No. (Field. No.)</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 60 (KW 788)</td>
<td>19.88 g</td>
<td>1/3</td>
<td>59.64 g</td>
</tr>
<tr>
<td>W 68 (KW 1168)</td>
<td>27.98 g</td>
<td>1/2</td>
<td>55.96 g</td>
</tr>
<tr>
<td>W 79 (KW 487)</td>
<td>42.62 g</td>
<td>2/3</td>
<td>63.93 g</td>
</tr>
<tr>
<td>W 93 (KW 1171)</td>
<td>85.49 g</td>
<td>3/2</td>
<td>56.99 g</td>
</tr>
<tr>
<td>W 129 (KW 849)</td>
<td>2,483 ±2 g</td>
<td>40 (5 minas)</td>
<td>62.08 g</td>
</tr>
</tbody>
</table>

From the above table we observe that the resultant unit for W 68 (KW 1168) is only 55.96 g, an unacceptably low value. In Petruso's (1992: 78) list of Aegean
weights there are no masses this low for a denomination of 1/2 unit. In all likelihood, therefore, this cylindrical piece represents a 3-unit weight of the Ugaritic/Syrian standard of ca. 9.3 g. As its shape and material are different from those of the other Uluburun domed and sphendonoid weights, it perhaps was a quick and practical replacement for a lost 3-unit hematite or other stone piece. In fact, one of the three domed weight sets proposed below is missing just such a 3-unit piece.

W 60 (KW 788), if not 1/50 of a double-mina piece, is probably a 1/3-unit specimen with a resultant unit mass of 59.64 g. Weights of similar mass from the Aegean system have already been listed (table 18). With regard to W 79 (KW 487), of 42.62 g, Petruso (1992: 79) lists three weights with corresponding mass values, one each from Ayia Irini, Akrotiri, and Knossos. W 93 (KW 1171), with its mass of 85.49 g, finds several similar examples in approximately the same mass range from Ayia Irini and Akrotiri. Moreover, lead-isotope analysis by Ashlan Yener, formerly of the Smithsonian Institution’s Conservation and Analytical Laboratory, strongly suggests that the lead for W 93 (KW 1171) was mined at Lourion, in Greece (A. Yener, personal communication). The other lead balance weights from Uluburun have not been submitted for such analysis. As for the heavy W 129 (KW 849), with its mass of 2,483 ± 2 g (-), we are hard pressed to suggest a convincing attribution to any mass standard. It must be remembered that the bronze or copper handle with which this weight was originally equipped is now missing. Without knowing the object’s original shape and size, it is difficult to suggest how much mass the piece may have lost. If we assume the handle was small and that the current mass of the weight approximates its originally intended value, however, it may represent a 5-mina piece with a resultant unit mass of 62.1 g.

One aspect of the Uluburun weight assemblage that is immediately noticeable is the absence of heavy weights and scales that could have been used to weigh the heavy cargo items on board, such as the copper and tin ingots. The weight specimens and pans recovered are not even sufficient to weigh much lighter cargo, the glass
ingots for example, unless of course each was weighed individually and a number of weight pieces were used simultaneously. This peculiarity is all the more striking in light of the many weight sets represented on the ship that were suitable for weighing smaller quantities of merchandise. With the possible exception of one large weight of 7,632 g (W 130 [KW 8309]), perhaps corresponding to 1,000 units of 7.63 g, no other pieces of stone appear to have been used as weights. This situation is in fact not unusual, as assemblages on land have suggested that weights of larger denomination, i.e., those too large to be carried with sets of smaller, distinctly shaped weight pieces, are usually in the form of cobbles and field stones. Courtois (1990: 119) reports that at Ras Shamra/Ugarit, where more than 600 weights have been found, weights in the 1 kg to 30 kg range are generally in the form of cobbles. This being the case, it is too early to rule out the absence of heavy weights from the Uluburun shipwreck, as there are a great number of mostly beach-polished stones that have been cataloged as ballast stones. Yet even if some of these ballast stones do prove to be weights, large weights in the talent range are unlikely to be represented, as the heaviest among them probably do not weigh more than a few kilograms. One group of artifacts that may incorporate heavy weights is the ship’s anchors. Twenty-four anchors were found on the Uluburun ship, but most are still in need of cleaning and the weights for only eight are known. Clearly, until they are fully studied, we cannot assess the use of any of them as weights for weighing copper and tin ingots. Among the 24 anchors, however, are two small specimens of white limestone (KW 2339 of 21,900 ± 2 g and KW 4418 of 25,932 ± 2 g). These two anchors are unlike any others on the ship in shape, size, and stone type used. Because of their diminutive sizes, we have surmised that they could have been anchors for the ship’s boat, weights attached to the hawsers of heavy anchors, or perhaps main sinkers for fishing nets, although they seem somewhat heavy for this last use. Alternately, it is possible that these two anchors represent heavy weights in the talent range. Dividing the masses of the two examples by 3,000 units (the number of shekels in a talent used along the Syro-Palestinian coast, as opposed to
the 3,600 shekels in the Mesopotamian talent), we obtain 7.30 g for KW 2339 and 8.65 g for KW 4418. The first value is notably reminiscent of the standard unit mass of ca. 7.4 g found among a set of sphendonoid weights in the Uluburun weight assemblage. This standard is structured to 50 shekels per mina, 60 minas per talent, thus 3,000 shekels per talent. It would seem then that stone anchor KW 2339 could represent a talent weight based on a standard unit mass of 7.3 g. Stone anchor KW 4418, however, yields a value of 8.65 g for the unit mass. This is considerably higher than the Mesopotamian standard that appears to be represented by at least one or possibly two sets among the Uluburun sphendonoids, with an average unit mass value of ca. 8.3 g. Consequently, anchor KW 4418 seems too heavy to represent a talent weight, at least of the unit mass of ca. 8.3 g. The Mesopotamian mina incorporates 60 shekels to the mina, 60 minas to the talent, and 3,600 shekels to the talent, which when divided into the mass of KW 4418, yields 7.2 g, a value far too low to represent the Mesopotamian unit. It seems, therefore, that even if anchor KW 4418 represented a 3,000 shekel talent, rather than one of 3,600 shekels, it yields too high a value for the unit mass of the Mesopotamian standard. Such being the case, then, one wonders how realistic it would be to view anchor KW 2339, which is very similar to KW 4418 in shape and size, as a talent mass of the 7.3 g standard. Furthermore, there is no third anchor of this type that may be attributed to the talent mass of a standard based on a unit mass of ca. 9.3 g, the standard most prominently represented by the Uluburun weights. Due to similar concerns, Bass (1967: 142) has considered the possibility that two large stones recovered from the Cape Gelidonya shipwreck are heavy weights for weighing the copper ingots carried aboard. These stones, weighing ca. 73,900 g (W 61) and 10,500 g (W 62), Bass tentatively attributed to unit masses of 12.3 g (based on 3,600 shekels to the talent) and 10.5 g (1,000 shekels), but suggested that only one of them should be considered as a weight, as it seemed unlikely that two separate standards would have been used for weighing the ingots. As with the Uluburun ship, the predominant standard unit mass of 9.3 g evident at Cape Gelidonya does not
appear to be represented by heavier denominations. It seems, then, that weights
greater than 100 shekels, or 2 minas, were not being carried on the two ships, at least
not in a form we can readily recognize.

*The Zoomorphic Weights.* The corpus of balance weights from Uluburun also
comprises a remarkable collection of weights in zoomorphic and anthropomorphic
forms. Nineteen such objects, all believed to have served as weights, are presented
with their unit attributions and resultant unit masses in table 22. While many of the
pieces are moderately well preserved, a few are seriously damaged. In the latter group
are two grossly damaged lead objects (W 138 [KW 4119], W 140 [KW 3845]) that
cannot positively be identified as zoomorphic weights. Both have been cracked
extensively by the expansion of their leaden cores, which probably explains why none
of their original bronze surfaces remain. That each piece originally had a bronze outer
surface is hinted by the extensive copper staining on one of these objects, unless the
staining is a result of contamination from the copper ingots under which it was found.
It is of course possible that these two lead objects are not balance weights at all. W
140 (KW 3845), while badly cracked and expanded, has a roughly sphendonoid shape.
It is primarily because of this shape that the piece has tentatively been cataloged as a
zoomorphic weight, as sphendonoid weight pieces were not made of lead. It is
possible, however, that W 140 (KW 3845) is an actual sling bullet, or ὀφενδόνη,
from which the name sphendonoid was coined by Evans because of the resemblance of
these weights to sling bullets. Sling bullets were cast in lead from the end of the Late
Bronze Age onward. On Cyprus, the first lead sling bullets are dated to the Late
Cypriot IIIA period of the twelfth century B.C.E., but a few examples may be earlier
(Åström and Nicolaou 1980: 29-30). It seems, then, that if W 140 (KW 3845) does
not represent the earliest evidence for lead sling bullets in the Levant, it is probably the
leaden core of a zoomorphic balance weight, perhaps one in the form of a duck or
goose. Whatever the case may be, the 17 remaining specimens from Uluburun still
constitute the largest set of zoomorphic weights from the Bronze Age. The Late Bronze Age (late-fourteenth century B.C.E.) hoard of 14 balance weights from Kalavassos-Ayios Dhimitrios, Cyprus, includes only 8 zoomorphic and anthropomorphic forms (Courtois 1983: 117-30).

Late Bronze Age weights in the form of animals were quite widespread in the ancient Near East and on Cyprus. Their use is depicted in tomb paintings and other representations from New Kingdom Egypt (Eran and Edelstein 1977: 57, n. 33; Petrie 1926: 6), and bronze zoomorphic weights (with and without lead cores) are known in some numbers from the Syro-Palestinian coast and Egypt. They were equally known and utilized on the island of Cyprus during the Late Bronze Age, as revealed by diverse finds made on several sites and by the important hoard discovered at Kalavassos-Ayios Dhimitrios in 1982 (Courtois 1983) as noted above.

Table 22. The Uluburun zoomorphic and anthropomorphic weights with possible unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Shape</th>
<th>Mass</th>
<th>Unit Attrib (7.5-8 g)</th>
<th>Unit Attrib (8.4 g)</th>
<th>Unit Attrib (9-9.9 g)</th>
<th>Unit Attrib (11-11.9 g)</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 131 (Lot 960)</td>
<td>Duck</td>
<td>1.46 g</td>
<td>1/5</td>
<td>1/5</td>
<td>1/5</td>
<td>--</td>
<td>7.3 g (-)</td>
</tr>
<tr>
<td>W 132 (KW 5841)</td>
<td>Calf (?)</td>
<td>2.03 g</td>
<td>1/4 (?)</td>
<td>1/4 (?)</td>
<td>1/4 (?)</td>
<td>--</td>
<td>8.12 g (-)</td>
</tr>
<tr>
<td>W 133 (KW 2128)</td>
<td>Fly</td>
<td>1.23 g</td>
<td>1/2</td>
<td>1/2</td>
<td>1/2</td>
<td>--</td>
<td>7.48 g (est.)</td>
</tr>
<tr>
<td>W 134 (KW 873)</td>
<td>Waterfowl/Grebe (?)</td>
<td>1.94 g</td>
<td>2/3</td>
<td>2/3</td>
<td>2/3</td>
<td>--</td>
<td>8.22 g (est.)</td>
</tr>
<tr>
<td>W 135 (KW 2736)</td>
<td>Bull</td>
<td>4.26 g</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>1/2</td>
<td>7.47 g (est.)</td>
</tr>
<tr>
<td>W 136 (KW 237)</td>
<td>Frog</td>
<td>6.62 g</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>2/3</td>
<td>9.38 g (est.)</td>
</tr>
<tr>
<td>W 137 (KW 4504)</td>
<td>Bull</td>
<td>5.22 g</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>9.55 g (est.)</td>
</tr>
</tbody>
</table>
Table 22, continued

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Shape</th>
<th>Mass</th>
<th>Unit Attrib (7.5-8 g)</th>
<th>Unit Attrib (8-8.4 g)</th>
<th>Unit Attrib (9-9.9 g)</th>
<th>Unit Attrib (11-11.9 g)</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 138</td>
<td>Unidentified</td>
<td>9.80 g (-)</td>
<td>--</td>
<td>1 (? )</td>
<td>1 (? )</td>
<td>--</td>
<td>9.80 g (-)</td>
</tr>
<tr>
<td>(KW 4119)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 139</td>
<td>Dog’s Head</td>
<td>10.28 g (-)</td>
<td>1-1/2</td>
<td>--</td>
<td>--</td>
<td>1 (? )</td>
<td>6.84 g (-)</td>
</tr>
<tr>
<td>(KW 4943)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 140</td>
<td>Unidentified</td>
<td>10.63 g (-)</td>
<td>--</td>
<td>1 (? )</td>
<td>1 (? )</td>
<td>--</td>
<td>10.63 g (-)</td>
</tr>
<tr>
<td>(KW 3845)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 141</td>
<td>Duck</td>
<td>8.33 g (-)</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>--</td>
<td>7.47 g (est.)</td>
</tr>
<tr>
<td>(KW 350)</td>
<td></td>
<td>11.21 g (est.)</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td>11.21 g (est.)</td>
</tr>
<tr>
<td>W 142</td>
<td>Calf</td>
<td>3.26 g (-)</td>
<td>1-1/2</td>
<td>1-1/2</td>
<td>--</td>
<td>--</td>
<td>16.94 g (est.)</td>
</tr>
<tr>
<td>(KW 727)</td>
<td></td>
<td>11.29 g (est.)</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td>11.29 g (est.)</td>
</tr>
<tr>
<td>W 143</td>
<td>Frog</td>
<td>19.52 g (-)</td>
<td>3 (?)</td>
<td>3 (?)</td>
<td>3 (?)</td>
<td>--</td>
<td>6.51 g (-)</td>
</tr>
<tr>
<td>(KW 220)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.76 g (-)</td>
</tr>
<tr>
<td>W 144</td>
<td>Bull</td>
<td>16.07 g (-)</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>2</td>
<td>10.0 g (est.)</td>
</tr>
<tr>
<td>(KW 335)</td>
<td></td>
<td>20.00 g (est.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 145</td>
<td>Lioness</td>
<td>26.77 g (-)</td>
<td>4</td>
<td>4</td>
<td>--</td>
<td>--</td>
<td>6.69 g (-)</td>
</tr>
<tr>
<td>(KW 3081)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.92 g (-)</td>
</tr>
<tr>
<td>W 146</td>
<td>Bull</td>
<td>54.97 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>5</td>
<td>10.99 g (-)</td>
</tr>
<tr>
<td>(KW 2050)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 147</td>
<td>Sphinx</td>
<td>80.70 g (-)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>--</td>
<td>8.52 g (est.)</td>
</tr>
<tr>
<td>(KW 468)</td>
<td></td>
<td>85.24 g (est.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 148</td>
<td>Lion</td>
<td>171.45 g (-)</td>
<td>--</td>
<td>20</td>
<td>20</td>
<td>--</td>
<td>8.57 g (-)</td>
</tr>
<tr>
<td>(KW 3292)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 149</td>
<td>Bucolic Scene</td>
<td>409.70 g (-)</td>
<td>--</td>
<td>50</td>
<td>50</td>
<td>--</td>
<td>8.19 g (-)</td>
</tr>
<tr>
<td>(KW 582)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Of the known ancient zoomorphic balance weights, one of the most frequently encountered animal shapes is the recumbent, couchant, or reclinig bovine. Weights shaped as bovine heads are also seen in some quantity. It is noteworthy, therefore, that the zoomorphic weight group from Uluburun does not include a single bovine
head save one piece of dubious identification (W 139 [KW 4943]). This object is so 
unlike any other bovine head that it probably represents some other animal, perhaps a 
wolf or a dog. On the other hand, we are not disappointed by the number of 
recumbent bovine figures in the collection. In addition to five bulls of various sizes is 
a newborn calf. The bovine theme thus constitutes 33% of the Uluburun zoomorphic 
material.

Weight pieces W 135 (KW 2736), W 137 (KW 4504), W 144 (KW 335), and 
W 146 (KW 2050), in the shape of couchant bulls with their heads turned to the right, 
assuredly represent one of the types most commonly found on Cyprus and in 
neighboring regions of the eastern Mediterranean. On Cyprus is a lead-cored bronze 
weight (Catling 1964: pl. 44c; Johnson 1980: 25 no. 151, pl. XXIX) from tomb 19 at 
Maroni that weighs 91.1 g (= 1 deben, or 10 shekels of 9.11 g), and two are known 
from Enkomi. One of the latter, discovered by chance in the site's northern section 
(Karageorghis 1964a: 310, fig. 31), weighs 172.9 g (= 2 deben, or 20 shekels of ca. 
8.65 g), and the second weighs 90.9 g (= 1 deben, or 10 shekels of 9.09 g) (Courtois 
1984b: 43 no. 407, fig. 15/36, pl. III). To these bovine-shaped weights of known 
provenance we may add another example, presumably from Cyprus, weighing 88.577 
g (Catling 1964: 251, pl. 44d; Karageorghis 1973: 16, 43, fig. 29, 110-11 no. 29; 

Ras Shamra (Ugarit) in Syria has produced more than half a dozen weights in 
the form of recumbent bovines (Schaeffer 1929: 287, fig. 2; 1937: 148-50, pl. XXIII: 
4; 1963: 209, fig. 25). Courtois (1983: 121) points out that some of these weights 
correspond to a mina of 437 g, a mina of 468/470 g, or to 20-shekels of 182 g at 9.1 g 
per shekel, and notes unpublished recumbent bovine weights of excellent quality.

Moving south along the Syro-Palestinian coast, we find recumbent bovines of 
the Late Bronze Age at Sarepta (Pritchard 1975: 69, fig. 62.6) and one in a tomb near 
Akko that weighs 47.8 g (Eran and Edelstein 1977: 57, fig. 25.24, 62 no.58). From 
Tel Nami we have a cow with a metal band folded around its neck for adjustment of
mass (Artzy 1993: 12); its mass is unknown to me.

Discovered at Tell el-Amarna in Egypt are two recumbent bovines (Pendlebury 1951: 109, pl. LXXVII.1, 125, pl. LXXVII.2). The larger weight is marked “5 deben” and weighs 437 g (1 deben = 87.4 g, or 1 shekel = 8.74 g). The second is marked “1 deben” and has a mass of 92.9 g (1 shekel = 9.29 g). Other recumbent bovines from Egypt of 1 to 2 deben are recorded by Petrie (1926: pl. IX).

Weight W 142 (KW 727), depicting a newborn calf with its head turned to the right and positioned above the rump, is perhaps one of the most naturally rendered weights of the Uluburun group. Certain aspects of the animal’s modeling convey the delicate features of a gazelle or a fawn, but the pronounced dewlap clearly identifies the figure as that of a newborn calf or bull calf. A much corroded, lead-filled zoomorphic weight from LCII Kition (Karageorghis 1985: 179, 290, pl. CLII.1267; Buchholz and Karageorghis 1973: 162, 746 no. 1737), in the form of a recumbent animal with its head positioned in a nearly identical manner, indicates that this naturalistic composition is not unique to the Uluburun weight. The Kition weight is identified as a goat but it may just as likely represent a calf, especially because of the shape of its muzzle and its larger and sturdier build. Badly corroded and cracked from the expansion of its leaden core, the piece is probably underweight 89.2 g (1 deben, or 10 shekels of 8.92 g each) but originally may have weighed 90-92 g.

Balance weights W 145 (KW 3081), and W 148 (KW 3292), in the form of a couchant lioness and lion, respectively, represent another animal shape seen in some numbers in the Near East. Ras Shamra/Ugarit has yielded at least three realistic examples of such felines (Schaeffer 1963: 209, fig. 25, inv. 23-475; Gray 1964: fig. 53), one of which is unpublished (inv. 23-354) but mentioned as weighing 91.25 g, or 1 deben (Courtois 1983: 122).

The weight hoard from Kalavassos included a somewhat crudely made lion weight of 159.2 g (K-AD 452) thought to represent 20 units of 7.96 g or 15 units of 10.61 g (Courtois 1983: 126, 127). Other lion or lioness weights come from Palestine
and are conveniently listed in Eran and Edelstein (1977: 57). There is a lioness from a tomb at Akko (Eran and Edelstein 1977: 57, 62, fig. 25:23, pl. XX:37); a lead-filled lion or lioness from Tell Abu Hawam (Hamilton 1935: 18, no. 39); a lion cub from Megiddo, found together with a perforated bull-shaped weight and balance pans (Loud 1948: pl. 240:3,5); a lion from Hazor (Yadin, et al. 1960: 159, pl. CXCVI: 14); and two others, one from 'En Shemer weighing 42.75 g (Eran and Edelstein 1977: 57) and another from Arad (Encyclopedia of the Holy Land I, 1975: 84). We also have from Nimrud in Mesopotamia a lion or lioness with a band of metal wrapped around its body (Braun-Holzinger 1984: pl. 74.383n), presumably for the adjustment of mass. In Egypt, both large lion weights of stone and the smaller bronze ones are found. Petrie (1926; cf. Eran and Edelstein 1977: 57, where the masses are given in grams instead of grains, as in Petrie) lists two of stone (no. 4991 [20 x 90.396 g] and no. 5215, pl. XVI [15 x 90.59 g]) and six of bronze (no. 47881 [1/2 x 8.036 g]; no. 4841 [20 x 8.456 g]; no. 4848 [20 x 8.557 g]; no. 5103 [2 x 10.01 g]; no. 5112 [1 x 10.17]; and no. 5260 [1 x 14.515 g]). Several bronze lions illustrated by Roeder (1956: 365-66, figs. 510-13), but with crossed fore paws unlike those of Uluburun, could also have served as weights; their weights are not indicated.

Duck-shaped balance weights, mostly of stone, occur commonly among weights of Mesopotamian origin. Those of bronze are much rarer, two of which are among the Uluburun zoomorphic weights (W 131 [Lot 960], W 141 [KW 350]). Another is among the zoomorphic weights from Kalavassos on Cyprus (Courtois 1983: 120, 123, pl. XVII.5). This lead-cored specimen, which probably depicts a goose rather than a duck, as revealed by its long neck, has an unusually high mass for a zoomorphic weight of such shape. Weighing 202 g, it is said to correspond to 24 shekels of 8.15 g or 25 shekels of 8.08 g, with either shekel being within the accepted range of the Mesopotamian standard. A second Cypriot bronze duck comes from Enkomi. With its mass of 24.6 g, it may correspond to 3 Mesopotamian shekels of 8.2 g.
Bronze ducks have been found in Mesopotamia at Khorsabad (Braun-Holzinger 1984: pl. 74, nos. 387-90) and two come from Alalakh in the Orontes basin that weigh 18.2 g (AT/38/133 [2 shekels of 9.1 g]) and 10.55 g (AT/47/31 [1 shekel]) (Arnaud 1967: 152, 154, 167). In Egypt is an example with a metal band wrapped around its neck, probably for fine adjustment of the piece's mass (Petrie 1926: pl. 9 no. 4815; Skinner 1954: 783, fig. 569; 1967: pl. 5; Weigall 1901: 386 no. 7056, pl. 5). With its total mass of 16.86 g, it probably corresponds to 2 shekels of 8.43 g. It is noteworthy that most duck weights of bronze seem to correspond to the Mesopotamian standard unit mass, and W 141 (KW 350) from Uluburun appears to be no exception. In the Bronze Age Near East, duck weights were common and often sculpted from semi-precious stones. They apparently became even more common during the first millennium B.C.E., and Courtois (1983: 123) mentions a series of beautiful ducks carved of basalt found at Tell Taynat near Alalakh. Yet a third bronze weight from Uluburun, W 134 (KW 873) of 1.94 g, superficially resembles a duck but its long, pointed, open beak is probably meant to represent a species of waterfowl, perhaps a grebe.

W 147 (KW 468), in the shape of a sphinx, is one of the best-preserved Uluburun zoomorphic/anthropomorphic weights. That the weight does not contain a lead core has saved it from cracking and splitting, but it is surprising that the piece does not include any lead, considering its high mass. Sphinx-shaped balance weights are non-existent outside of Egypt, except for one possible example from Byblos (Dunand 1954: pl. CXVI, no. 14499; Jidejian 1968: 24). Covered with gold foil, this extraordinary specimen is much more finely detailed than W 147 (KW 468), although its composition and rendering are somewhat stilted. Recovered from the Middle Bronze Age Temple of the Obelisks, the sphinx was discovered with many other bronzes among a hoard of temple offerings. The context in which it was found, as well as its ornate gold-leaf sheathing, suggest that the object was probably, but not necessarily, used as a weight piece in the Temple, perhaps to weigh temple-bound
donations, offerings, and other goods sent there. It is also possible of course that it
was originally cast to serve as a weight and later gilded as an offering to the Temple.

Aaron J. Paul, Curatorial Assistant of the Harvard University Art Museums,
has called to our attention the existence of a lead-cored sphinx in their collection. Of
unknown provenance, though said to be from Sparta, this weight is only slightly longer
than the Uluburun piece, but it is more than twice as heavy, with a mass of 175.47 g.
Stylistically, it has been dated to about 700 B.C.E., with facial features, especially the
nose, consistent with the Archaic period. It is generally closer in appearance to the
Uluburun sphinx than to the detailed but stiff sphinx from Byblos. At present, the
nature of this balance weight cannot be stated with any greater certainty. In his study
of Egyptian bronze figures, Roeder (1956: 370) lists several bronze sphinxes from
Egypt, but it is not certain that these small bronze figurines were intended as balance
weights.

A zoomorphic weight unique to the Uluburun group is W 133 (KW 2128). It
takes the form of a fly, which, like the sphinx, is an Egyptian motif. This remarkable
object, with a preserved mass of only 1.23 g, is the lightest of the zoomorphic weights,
though, with slightly damaged wing tips and notable surface erosion, it is far lighter
than originally intended. Such light zoomorphic weights are seldom found at other
sites, making the Uluburun fly unique with regard not only to shape but also to mass.

Two of the bronze Uluburun balance weights are in the shape of frogs. The
smaller of the two (W 136 [KW 237]), weighing 6.62 g, is fairly well preserved, but its
larger counterpart (W 143 [KW 220]), with a preserved mass of 19.52 g, is severely
damaged due to the expansion of its leaden core. Almost all of the this frog’s back is
missing, as are the tips of its forelegs. Balance weights in the shape of frogs and toads
are extremely rare in the Near East and Cyprus, especially when of bronze, but they do
occur in Egypt. Petrie (1926) lists two bronze toads (no. 5264, mass 58.94 g [4
units]), one of which has a lead core (no. 5245 of 42.44 g [3 units]), and five frogs
(no. 4986 of 17.96 g [2 units]; no. 5083 of 9.74 g [1 unit]; no. 5146 of 11.87 g [1
unit]; no. 4775 of 8.03 g [1 unit]; no. 4913A of 17.96 [2 units]). The units are presumably of 9.3 g each.

Zoomorphic weight W 139 (KW 4943) is in the form of an animal’s head with an unusually long neck. Although the piece includes a lead core, its bronze shell is not cracked or deformed. Even so, the animal represented by this specimen is difficult to identify, primarily because of its highly stylized and vague rendering. The animal’s pointed muzzle and small head evoke canine features, but its long, thick neck and angular skull base bear bovine or ovid/caprid features. We have many bronze zoomorphic weights from the Late Bronze Age eastern Mediterranean that are shaped as bull and bull-calf heads and, consequently, one would normally be tempted to attribute the Uluburun specimen to that well known and common form. Its neck is quite thick like that of a bull but it is conical and it does not possess the dewlap found on many of the bull-head weights modeled with a portion of the animal’s neck. Nor does it exhibit protrusions or stubs on each side of the head to represent horns and ears. The shape, angle, and position of the single pair of stubs look like canine ears and are directed toward the animal’s back, rather than to its sides as would be the case with a bull, cow, or calf. Furthermore, the head of the Uluburun weight is rather small in relation to the neck, which contradicts the proportions seen on bull-head weights. Unless W 139 (KW 4943) represents an extremely poorly rendered bovine head, then, we are inclined to identify it as a canine head, perhaps that of a wolf or dog.

There are no good parallels for W 139 (KW 4943), but a crude bull head from the hoard of balance-weights from Kalavassos (Courtois 1983: 119, 120, pl. XVII.12; South, Russell and Keswani 1989: 26, 122, fig. 24, K-AD 445, pl. IX, K-AD 445) may be said to show some remote resemblance. The Kalavassos zoomorphic weights display varying degrees of expertise and craftsmanship, but K-AD 445 is a crudely made bull’s or cow’s head, obviously the work of a less skilled craftsman. This weight displays rudimentary horns (pointed outward) with ears, nose, and mouth ineptly rendered. Like the Uluburun specimen, it is filled with lead and the base of the neck is
circular in section. In the same group are two other weights in the form of bull’s and
calf’s heads, again executed in a rather stilted, unnatural style. These two heads are
complete with horns, pronounced ears, and clearly detailed eyes, nostrils, and mouths.
The calf’s-head weight has a lead core while the bull’s head weight is solid bronze.

Other bovine head parallels outside Egypt are few. A lead-filled bronze bull’s-
head weight of 73.6 g (probably 8 shekels of 9.2 g each) was found in the Diktaean
cave on Crete (Evans 1906: 353, fig. 9; Glotz 1952: 224; Boardman 1961: 52 no. 228,
pl. XVI.228, Petruso 1978: 128, 203 no. 271, 252, fig. 56), and we have a calf’s head
from Knossos that weighs 5.15 g (Boardman 1961: 49 n. 2; Petruso 1978: 180 no.
77).

Four bronze bull’s-head weights and one bull-calf’s head weight from Egypt
are listed by Petrie (1926). One of the bull’s heads and the calf’s head are quite
skillfully crafted and realistically rendered and appear on the frontispiece of the book.
The bull calf’s head (no. 4939) is from Amarna and, weighing 87.75 g, probably
represents 10 units, or 1 deben. The other bull’s head weights listed in Petrie are: no.
4816 of 162.67 g (probably 20 units); no. 4925 of 8.72 g (1 unit); no. 5030 of 19.62 g
(2 units); and no. 5073 of 9.88 g (1 unit). Again, the units are presumably of ca. 9.3 g.

Finally, the most remarkable balance weight from Uluburun, without doubt, is
W 149 (KW 582). This unique weight piece comprises a cylindrical, lead-filled bronze
base surmounted by a serene bucolic scene of a herdsman kneeling before three calves,
one of which has been lost. While cylindrical bronze weights with lead-filled cores and
domed tops occur in Egypt, the Near East, and on Cyprus, the Uluburun piece, with
its free-standing figurines, is unique in the corpus of Late Bronze Age Mediterranean
weights.

The cylindrical base has concave sides and a slightly domed top. In certain
respects, the form resembles the well-known “cupcake-shaped” weights of Near
Eastern, Cypriot, and Egyptian origin, but differs in that its lower half widens toward
the base surface. The bronze outer shell is seriously cracked and exfoliated, and
missing in many areas, due largely to the expansion of the leaden core. The lower portion of the base has generally sustained extensive damage; nothing of the original base edge survives. Nevertheless, the preserved original surface is sufficient to reveal the original shape of this cylindrical base.

The most unusual aspect of this extraordinary weight, however, lies with the small bronze figures embellishing its domed top. Here were originally three recumbent calves, though one has since become detached and lost, presumably after the sinking of the ship. That these three animals are indeed bovines and not sheep, as identified earlier (Pulak 1988: 31), is clearly revealed by their long tails resting on their rumps and backs. The head of the central calf is turned to its right, while the other looks directly at the kneeling herdsman before it. Three small bovine weights found at Uluburun were examined to determine if they originally may have been part of W 149 (KW 582). Two of the three may be conclusively eliminated from consideration, but we cannot be certain about lead-cored bull/calf weight W 132 (KW 5841). It is the only lead-cored bovine weight with the appropriate size and posture, but its poorly preserved and fragmentary condition prohibits confident attribution to W 149 (KW 582). The herdsman, wearing a cap and cloak, kneels on the left leg with his left hand resting on his knee. The rather short right leg is tucked up against his chest and the right hand is spread, palm down on the ground. Although his nose is slightly damaged, details of his facial features are still clear.

Among the hoard of balance weights from Kalavassos are three lead-filled bronze weights of cylindrical form topped with a low dome (Courtois 1983: 119, 123-25, 126-27, pl. XVII.6, 7, 15; South, Russell and Keswani 1989: 26, 122, fig. 25, pl. IX). Of these, the smallest (K-AD 447), weighing some 230 g, is plain. The remaining two (K-AD 448 and K-AD 449), the heaviest weights in the hoard, weigh 487.5 g and 581.9 g, respectively. Each piece includes on its top surface a relief of two crossed animals, and raised rings around its upper, central, and base sections. As with the Uluburun specimen, these are also without good parallels from the corpus of
eastern Mediterranean Bronze Age weights. But, lead-cored balance weights with inverted truncated cones and plain domed tops are found on Cyprus. Three such weights were recovered from a site near Maroni (Johnson 1980: 17, 58, pls. XII, LXII). Two weigh 97.4 g (no. 43) and 94.1 g (no. 44), the latter corresponding to 1 deben, or 10 shekels of 9.41 g. A similar weight of 266 g was part of the “Bronze Hoard” found at Enkomi (Schaeffer 1952: 39-41). Another weight from Enkomi, similar in shape to the Uluburun piece, but with a loop handle attached to its domed top, bears on its side a series of animals in low relief (Lagarce 1971: 411, 413, 418, figs. 22c-d, 420, figs. 23a-b, 422, fig. 24.2).

Three of the Uluburun zoomorphic weights must have been used frequently enough to warrant their storage with the more common types of weights; even the smallest of the forms, we may now be sure, were used for weighing and were not amulets or the like, as has been suggested (Eran and Edelstein 1977: 58).

**Summary and Conclusions**

Of the 149 objects cataloged as balance weights or possible balance weights from the Uluburun shipwreck, only 85 are preserved well enough to be included in analyses aimed at determining their standard unit masses. Of the non-useable pieces, 8 stone weights probably suffered damage during the sinking of the ship; 13 bronze weights of sphendonoid and domed shape are severely altered or deformed from corrosion; 17 additional pieces, also of metal, appear to be intact but have lost much of their masses and no longer correspond to their originally intended weights. The same is true of all the zoomorphic weights, some of which have suffered extensive damage, especially those with lead cores. One weight has been excluded for its excessive size, as have five others because they either include metal suspension loops, or are provided with holes for such.

The Uluburun weights were initially attributed to their respective denominations based on an intuitive analysis. Such an analysis allows for the testing of
plausible and logical utilitarian relationships within the weight assemblage that would not be possible using only statistical methods. Accordingly, the mass of each well-preserved weight was divided by the unit mass value that is suspected of being represented by the group. One should thereby obtain for most specimens reasonable fractional and multiple denominations of that standard. The analysis revealed that most of the intact sphendonoid and domed weights from Uluburun show overwhelming evidence for the existence of a system based on a unit mass of ca. 9.3 g.

By then subjecting the same assemblage of weights to a much wider range of possible mass standards, without restriction to any specific mass standard or morphological group, one should be able to assess objectively, by statistical analysis, which values correspond to the most likely standard unit mass of the weight population as a whole. Therefore, the Uluburun weights were analyzed by a statistical (Kendall’s) approach that is devoid of bias toward any mass standard. Based on the search among only the well-preserved, non-metallic weights from Uluburun, irrespective of size and shape, the statistical analysis has revealed convincingly that for the great majority of balance weights, a standard whose unit mass is ca. 9.3 g seems to satisfy the group best. This corroborates the outcome of our intuitive analysis. The standard unit mass of ca. 9.3 g corresponds to the Ugaritic/Syrian shekel, a standard used all along the Syro-Palestinian coast, especially in the north, and on Cyprus. The statistical analysis has suggested the presence of at least two additional mass standards, however, one in the vicinity of 7.4 g, the other ca. 8.3 g. The former value conforms to the standard known as the peyem, which ranges in mass from ca. 7.4 g to ca. 8 g, and the latter probably corresponds to the Mesopotamian shekel whose unit mass ranges from ca. 8.1 g to ca. 8.5 g. It is possible that there is yet a fourth standard represented by several weights, too few to comprise a functioning set, based on the necef standard of ca. 10.5 g. As nearly all of them represent 1-unit denominations, it is highly likely that some of these weights are overweight examples of the ca. 9.3 g shekel. Thus, all of the best candidates for the unit masses of the assemblage, as
revealed by Kendall’s statistic, correspond to known Near Eastern mass systems (or their multiple or fractional units).

Division of the Uluburun weight assemblage into the two major groups based on recognizable shapes (i.e., sphendonoid and domed) revealed readily that the domed weights, for the most part, fall into neat clusters centered on multiples of a standard unit mass of 9.3 g, while the lesser unit masses of ca. 7.4 g and 8.3 g are found almost exclusively among the sphendonoids. Of these lighter standards, there appears to be only a single set for the 7.4 g standard and at least one, and possibly two, for the 8.3 g standard. That only one or two basic sets are represented for these standards is in itself sufficient to reveal that they were not used in everyday weighing transactions involving bulk merchandise, as their limited mass ranges would have essentially prohibited mensuration of heavy everyday merchandise. Rather, these sets were probably kept on the ship for use by an assayer when weighing precious metals, and perhaps performing conversions to other mass standards. On the other hand, there were probably at least four separate sphendonoid sets based on a unit mass of ca. 9.3 g, which along with the standard evident for most of the domed pieces, suggests that the great majority of transactions were conducted according to this standard.

It is noteworthy that the sphendonoid and domed weights occur in identical denominations within the mass range common to both shapes. That is, sphendonoid fractional and multiple units of 1/2, 2/3, 1, 2, 3, 5, and 10 are also present for the domed weights. Yet the domed weights include higher denominations of 20, 30, 50 (1-mina), and 100 (2-mina) multiples not found among the sphendonoids, which, in turn, incorporate smaller fractional denominations of 1/6- and 1/3-units (perhaps also 3/4-units) that were not incorporated into the domed sets. It is thus apparent, from their greater number of heavier pieces, that the domed weights were used primarily in transactions involving heavy and probably bulk or coarse merchandise. In fact, more than half of the balance weights in this group weigh 10 units or more, and only four of the 40 represent fractional units. In contrast, what is immediately clear in the
Sphenodonoid assemblage is the presence of smaller denominations, with many fractional units, and no weights attributable to more that 10 units. The sphenodontoids thus comprised the precision weights, some of which were finely adjusted to the desired mass by adding lead plugs. They were reserved almost certainly for accurately measuring small quantities of precious metals such as gold, silver, and perhaps also spices, all of which were found in quantity on the wreck.

Five weights are provided with holes for suspension, two of which still retain their metal rings. Others may also have been originally fitted with metal loops that would have rendered them heavier than their current masses. Designed specifically for suspension, hence easy access, these weights almost certainly represent personal weights carried on the merchants themselves, rather than representing elements of utilitarian weights sets stored in leather pouches. As such, these special-purpose weights could be put to use readily, and their particular denominations probably facilitated the weighing of specific quantities of certain materials for special purposes, such as determining the amount of tax or commission on each transaction. The heaviest of these pierced weights, preserved with its metal ring, is a 10-unit piece of 9.5 g shekels. A second large specimen, but without a metal ring, may correspond to 10 units of 7.4 g each, or more if originally provided with a metal ring. Other pierced weights probably correspond to 3 units of 9.7 g each, 1 unit of 10.61 g, and a 2/3-unit of 9.06 g; all three standards seem to be represented among the Uluburun sphenodontoids.

As the Uluburun weight assemblage is the largest and most complete group of contemporaneous Late Bronze Age weights to have come from a closed-context site, all standards and sets necessary for an effective maritime merchant venture may be expected. The weight pieces conforming to these norms constitute different groups, each comprising one or more weight sets with sufficient individual elements of various denominations to permit convenient and effective weighing in most cases. According to their morphology, nearly all of the 40 domed weights from Uluburun may be
assigned to three separate sets without great difficulty.

It seems then, that there were at least seven (four sphendonoids, three domed) sets on the ship that were structured to a norm of ca. 9.3 g. At least two additional sphendonoid sets incorporated standards of 7.4 g and 8.3 g. These results suggest that the mass standard most commonly used by the merchants on board was one based on a unit mass of ca. 9.3 g. If we assume that each merchant possessed one of each weight set, then at least three merchants would have been aboard ship, each equipped with a sphendonoid set for accurate weighing of small, valuable commodities, and one domed set for weighing bulkier merchandise, both factored to a unit mass of ca. 9.3 g.

These sets and the standards they incorporate also may be taken as near-conclusive evidence that Semitic merchants were aboard. More may be said about the number and ethnicity of the merchants and/or passengers on the ship after the entire artifact assemblage has been studied in detail. The absence or near absence of weights based on the Aegean standard, however, is puzzling if at least two Mycenaeans were accompanying the venture, as suggested by the pairs of Mycenaean personal possessions we have recovered. Perhaps these Mycenaeans were political envoys or representatives charged with escorting, presumably to a Mycenaean port, the goods on the Uluburun ship. In any case the quantities of cargo items and merchandise probably would have been verified by recounting and reweighing at the port of destination.
CHAPTER IV
THE CAPE GELIDONYA BALANCE WEIGHTS

Preliminary Remarks

Between June 1 and September 7, 1960, George F. Bass of the University of Pennsylvania began and completed the excavation of a Late Bronze Age merchantman at the southern coast of Turkey, on the northern extremity of the largest of a group of five islands off Cape Gelidonya. The ship had settled with its stern on a large boulder and its bow on a flat sea floor of rock, between 26 and 28 m deep.

This was the first shipwreck excavation to have been carried to completion on the sea bed by diving archaeologists and the first conducted to the standards of terrestrial excavations. The sinking of the ship has been dated to 1200 B.C.E. ±50 years by radiocarbon analyses of brushwood from the wreck, and to the late thirteenth century B.C.E. by two Mycenaean stirrup jars discovered on surveys to the site subsequent to the excavation. Because the sea bed at Cape Gelidonya is rocky, with little sand to cover and protect wooden hull remains, most of the ship's hull had been completely lost, but the distribution of the cargo suggested that it was about 10 m long.

The bulk of the cargo consisted of ingots of copper and tin, ingredients for making bronze, and scrap bronze tools from Cyprus and the Syro-Palestinian coast intended for recycling. These tools make up the largest assemblage of Bronze Age farming implements known. There are broken plowshares, axes, adzes, chisels, pruning hooks, and a spade. Also found were knives, spearheads, a sword, and casting waste.

The ship's Cypriot copper cargo was shipped as 34 flat, four-handled ingots of the oxhide type, and discoid "bun ingots," as well as chiseled fragments of each type. Additionally, there were 18 flat, ovoid ingots of much smaller size, at least one of which was bronze. Poor preservation of the tin ingots prevented discernment of their
original shapes, but evidence gathered from the sea floor suggested a rectangular bar shape for one of them.

The discovery on the site of a bronze swage block, two stone hammer heads, stone polishers, a whetstone, and a large, flat, close-grained stone that could have served as an anvil suggested to Bass that an itinerant smith or tinker may have been on board. Moreover, the excavation revealed what may be considered personal possessions of crew and passengers in the area designated as the ship's stern, apart from the mostly Cypriot cargo, and the mixture of Mycenaean, Cypriot, and Syrian pottery found on the site. Among these personal possessions were four scarabs, a scarab-plaque, an oil lamp, stone mortars, an Egyptian-type razor, and a cylinder seal of Syrian or Canaanite origin (Bass 1967; 1973).

Bass's study of the artifacts from the ship suggested to him that the generally accepted view of a virtual Mycenaean Greek monopoly on maritime commerce in the eastern Mediterranean, and the belief that Phoenician seafarers did not begin their great maritime tradition until the following Iron Age, was incorrect. Based on comparisons of the wreck material with similar objects found on land, Bass concluded that the Cape Gelidonya ship was probably Canaanite or Cypriot in origin and that Semitic seafarers enjoyed an important share of the maritime trade, especially in raw materials and metals.

Bass published in 1967 a detailed report of his excavation at Gelidonya. The provenance of nearly every object recovered during the excavation was shown precisely on the published plans of the site. Thanks to these detailed plans, the locations of many of the balance weights from the wreck are known with certainty. A total of 62 stone and metal objects interpreted as possible balance weights, along with two very large stones regarded as possible heavy weights (Bass 1967: 136-37, 142), were cataloged. Bass presented an exemplary analysis of these objects and concluded that the assemblage incorporated eight ancient mass standards, with the Egyptian qedet the most commonly represented.
Bass (1967: 135) noted that many of the balance weights were among the smallest objects on the site and, therefore, were the most likely to have been recovered out of context. Some were discovered a year after the completion of the excavation, when many pieces of concretion, initially put aside after having been broken into small pieces, were later broken down further in a last search for small finds. Because of their diminutive sizes and irregular, pebble-like appearances, it was quite likely that some of these balance weights, especially the smallest, were overlooked during the course of the excavation. Bass pointed out, on the other hand, that his recovery of five of the unit weights of seven weight standards apparently represented on the ship, being the smallest and, therefore, the most easily missed, indicated that few weights were overlooked. All the weights, with two exceptions (W 55n [W 52] and W 64n [W 60]), were found on the part of the wreck that almost certainly corresponded to the stern section of the ship, from either area G (the stern section) or area M, where many small objects from G seemed to have been carried by the current (fig. 11). Bass, however, notes only W 64n (W 60), which was firmly fixed with a number of bronze tools in area P VII, as being distinctly separate from the others.

That some weights were overlooked during the excavation is confirmed by the discovery during visits to the site between 1987 and 1989 of three balance weights in the immediate area of the large boulder that dominates the site. Two of these balance weights (W 26n [W 63], W 7n [W 64]) were found together, deep under sand inside a natural fissure covered over with encrustation, just outside area M II. The weights had to be carefully extracted from the encrustation that completely obscured them, causing them to be overlooked in 1960. Such fissures crisscross the entire flat limestone seabed just downslope of the area on where the ship came to rest. It is quite likely, therefore, that additional weights and other objects lodged in the fissures await discovery. A third weight (W 17n [W 65]) was found nearby in M1, while a fourth (W 65n [W 66]) was recovered about 16 m east of the large boulder.
Fig. 11. Site plan (after Bass 1967) of the Cape Gelidonya shipwreck with locations of weights and their types indicated.
For the purpose of this study, a thorough search in the store rooms of the Bodrum Museum of Underwater Archaeology produced all but two (W 5n [W 6] and W 21n [W 19]) of the Cape Gelidonya balance weights cataloged by Bass in 1967, and one additional weight (W 58n [W 67]) that was inadvertently omitted from the original publication. After nearly 35 years of storage in the less than ideal climatic conditions of the medieval castle housing the Bodrum Museum, many of the balance weights exhibited extensive surface deposits due to the migration of absorbed sea salts. Moreover, some of the balance weights still retained small to moderate amounts of the original calcareous marine encrustation that would have caused the weights to register higher mass values than originally intended. Such overweight pieces, unless completely cleaned, are not suitable for analyses that seek to determine their common unit mass or masses. In order to arrive at an accurate value for the mass of each balance weight in this most important collection, therefore, it was clear that removal of surface deposits and extensive desalination was necessary. The sometimes cement-hard surface encrustation and the caked sea salts were delicately removed by mechanical means, after which the pieces were desalinated for approximately one year. During the latter process, the water was changed at regular intervals and its conductivity monitored to assure complete removal of salts. Often the original catalog and field identification numbers on the weights were found to have been obliterated by salt crystals. Consequently, each weight was remeasured, reweighed, and compared with museum archive photographs to ensure that its identification, as published by Bass, was retained.

The catalog of the Cape Gelidonya balance weights presented in this study, therefore, reflects the new mass and dimensions of each weight after complete cleaning and desalination. Both the new and the old masses of each weight are indicated in order to facilitate comparison. It will be observed that the mass values published in the final excavation report are in most instances fairly close to those taken recently
with a modern electronic scale, but due to the additional cleaning and desalination, they are now generally lower.

**The Weight Assemblage**

The excavation registration number and provenance of each weight are found in the catalog (Appendix D). Provenances are designated as single letters G (gully), M (miscellaneous), P (platform), and S (sand), each corresponding to a specific part of the site. As in the original publication, the weights tabulated below are also in order of ascending mass. Each weight is assigned a new consecutive catalog number preceded by the letter “W,” for weight, and followed by the letter “n,” for new, the latter to distinguish the new numbers used in this study from those in the original publication. The original publication number of each weight, as published by Bass (1967: 136–37, 142), appears in the second column. The location of each area (locus) is shown in figure 11. All masses are cited in grams, abbreviated g. A minus sign (-) following a citation of mass indicates that the piece is damaged and obviously underweight.

Estimations of the original masses of damaged weights have been obtained by first restoring the weight's form with plasticine and then taking its weight in water with a hydraulic balance. To obtain each piece's original mass, the calculated original volume is then multiplied by the density or specific gravity specifically calculated for each weight. The extreme care with which these procedures have been performed has resulted in the very close approximation of a weight's mass before damage. The methodology is detailed in Appendix B. Calculated masses thus obtained are indicated by the abbreviation (cal.). A conservative density value for copper is used for metal "weights" whose original densities cannot be calculated; their estimated masses are followed by the abbreviation (est.). Methods of cataloging, weighing, and measuring were conducted as for the Uluburun balance weights.

In addition to the 60 pan-balance weights and the two large stones cataloged by Bass as possible weights, the new catalog presented here includes a weight not
previously cataloged (W 58n [W 67]) and four others (W 26n [W 63], W 7n [W 64], W 17n [W 65], W 65n [W 66]) discovered on the site by the Institute of Nautical Archaeology between 1987 and 1989 (table 23). In order to avoid confusion that could result from modifying the published numbers of the Gelidonya balance weights, these five new weights originally were appended to the end of the list. For practical considerations, however, the complete assemblage has been rearranged to incorporate all the weights in order of ascending mass value, with the newly added weight numbers in parentheses under the heading "Pub. No."

Table 23. The Cape Gelidonya balance weights.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>W 1n</td>
<td>W 1</td>
<td>Domed</td>
<td>Limonite</td>
<td>3.50 g</td>
<td>3.41 g</td>
<td>--</td>
</tr>
<tr>
<td>W 2n</td>
<td>W 2</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>9.30 g</td>
<td>9.34 g</td>
<td>I</td>
</tr>
<tr>
<td>W 3n</td>
<td>W 3</td>
<td>Domed</td>
<td>Marl (?)</td>
<td>9.50 g</td>
<td>9.43 g</td>
<td>--</td>
</tr>
<tr>
<td>W 4n</td>
<td>W 4</td>
<td>Domed</td>
<td>Hematite</td>
<td>10.30 g</td>
<td>10.19 g</td>
<td>--</td>
</tr>
<tr>
<td>W 5n</td>
<td>W 6</td>
<td>Domed</td>
<td>Hematite</td>
<td>12.30 g</td>
<td>Missing</td>
<td>--</td>
</tr>
<tr>
<td>W 6n</td>
<td>W 5</td>
<td>Cylindrical</td>
<td>Bronze</td>
<td>10.50 g</td>
<td>10.13 g (-)</td>
<td>14.79 g (est.)</td>
</tr>
<tr>
<td>W 7n</td>
<td>(W 64)</td>
<td>Sphendonoid</td>
<td>Marl (?)</td>
<td>--</td>
<td>18.09 g</td>
<td>--</td>
</tr>
<tr>
<td>W 8n</td>
<td>W 8</td>
<td>Conical</td>
<td>Bronze</td>
<td>17.80 g</td>
<td>17.80 g (-)</td>
<td>20.42 g (est.)</td>
</tr>
<tr>
<td>W 9n</td>
<td>W 10</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>20.80 g</td>
<td>20.48 g</td>
<td>--</td>
</tr>
<tr>
<td>W 10n</td>
<td>W 9</td>
<td>Lentoid</td>
<td>Hematite</td>
<td>20.60 g</td>
<td>20.53 g</td>
<td>--</td>
</tr>
<tr>
<td>W 11n</td>
<td>W 11</td>
<td>Pyramidal</td>
<td>Hematite</td>
<td>26.10 g</td>
<td>25.79 g</td>
<td>--</td>
</tr>
<tr>
<td>W 12n</td>
<td>W 12</td>
<td>Domed</td>
<td>Hematite</td>
<td>26.20 g</td>
<td>26.05 g</td>
<td>--</td>
</tr>
<tr>
<td>W 13n</td>
<td>W 7</td>
<td>Irregular</td>
<td>Bronze</td>
<td>16.00 g</td>
<td>15.51 g (-)</td>
<td>26.89 g (est.)</td>
</tr>
<tr>
<td>---------</td>
<td>----------</td>
<td>----------</td>
<td>--------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>W 13n</td>
<td>W 7</td>
<td>Irregular</td>
<td>Bronze</td>
<td>16.30 g</td>
<td>15.51 g (-)</td>
<td>26.89 g (est.)</td>
</tr>
<tr>
<td>W 14n</td>
<td>W 13</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>28.00 g</td>
<td>27.98 g</td>
<td>--</td>
</tr>
<tr>
<td>W 15n</td>
<td>W 14</td>
<td>Sphendonoid</td>
<td>Hematite (?)</td>
<td>29.20 g</td>
<td>28.79 g</td>
<td>--</td>
</tr>
<tr>
<td>W 16n</td>
<td>W 15</td>
<td>Pyramidal</td>
<td>Hematite</td>
<td>29.80 g</td>
<td>29.42 g</td>
<td>--</td>
</tr>
<tr>
<td>W 17n</td>
<td>(W 65)</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>--</td>
<td>30.43 g</td>
<td>--</td>
</tr>
<tr>
<td>W 18n</td>
<td>W 17</td>
<td>Domed</td>
<td>Ilmenite (?)</td>
<td>36.00 g</td>
<td>35.83 g</td>
<td>--</td>
</tr>
<tr>
<td>W 19n</td>
<td>W 18</td>
<td>Domed</td>
<td>Hematite (?)</td>
<td>36.50 g</td>
<td>36.19 g (-)</td>
<td>36.77 g (cal.)</td>
</tr>
<tr>
<td>W 20n</td>
<td>W 16</td>
<td>Domed</td>
<td>Hematite</td>
<td>35.00 g</td>
<td>27.32 g (-)</td>
<td>35.0 g (est.)</td>
</tr>
<tr>
<td>W 21n</td>
<td>W 19</td>
<td>Irregular</td>
<td>Hematite</td>
<td>42.70 g</td>
<td>Missing</td>
<td>--</td>
</tr>
<tr>
<td>W 22n</td>
<td>W 20</td>
<td>Domed</td>
<td>Hematite</td>
<td>43.80 g</td>
<td>43.69 g</td>
<td>--</td>
</tr>
<tr>
<td>W 23n</td>
<td>W 22</td>
<td>Sphendonoid</td>
<td>Hematite (?)</td>
<td>44.80 g (-)</td>
<td>44.79 g (-)</td>
<td>45.31 g (cal.)</td>
</tr>
<tr>
<td>W 24n</td>
<td>W 21</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>45.50 g (-)</td>
<td>45.50 g (-)</td>
<td>47.60 g (cal.)</td>
</tr>
<tr>
<td>W 25n</td>
<td>W 23</td>
<td>Domed</td>
<td>Ilmenite (?)</td>
<td>47.70 g</td>
<td>47.70 g</td>
<td>--</td>
</tr>
<tr>
<td>W 26n</td>
<td>(W 63)</td>
<td>Domed</td>
<td>Hematite</td>
<td>--</td>
<td>47.78 g</td>
<td>--</td>
</tr>
<tr>
<td>W 27n</td>
<td>W 24</td>
<td>Domed</td>
<td>Hematite</td>
<td>48.20 g</td>
<td>47.95 g</td>
<td>--</td>
</tr>
<tr>
<td>W 28n</td>
<td>W 25</td>
<td>Sugar-loaf</td>
<td>Hematite</td>
<td>49.40 g</td>
<td>49.11 g</td>
<td>--</td>
</tr>
<tr>
<td>W 29n</td>
<td>W 26</td>
<td>Domed</td>
<td>Hematite (?)</td>
<td>51.50 g</td>
<td>51.35 g</td>
<td>--</td>
</tr>
<tr>
<td>W 30n</td>
<td>W 27</td>
<td>Domed</td>
<td>Hematite</td>
<td>54.20 g</td>
<td>53.61 g</td>
<td>--</td>
</tr>
</tbody>
</table>
Table 23, *continued*

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>W 31n</td>
<td>W 28</td>
<td>Domed</td>
<td>Hematite</td>
<td>55.50 g</td>
<td>53.90 g</td>
<td>--</td>
</tr>
<tr>
<td>W 32n</td>
<td>W 29</td>
<td>Domed</td>
<td>Hematite</td>
<td>56.00 g (-)</td>
<td>55.79 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>57.45 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 33n</td>
<td>W 30</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>57.50 g</td>
<td>57.20 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58.18 g (cal.)</td>
<td></td>
</tr>
<tr>
<td>W 34n</td>
<td>W 31</td>
<td>Domed</td>
<td>Hematite</td>
<td>59.00 g</td>
<td>58.79 g</td>
<td>--</td>
</tr>
<tr>
<td>W 35n</td>
<td>W 32</td>
<td>Sphendonoid</td>
<td>Magnetite (?)</td>
<td>63.90 g</td>
<td>63.41 g</td>
<td>--</td>
</tr>
<tr>
<td>W 36n</td>
<td>W 34</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>65.50 g</td>
<td>65.29 g</td>
<td>--</td>
</tr>
<tr>
<td>W 37n</td>
<td>W 35</td>
<td>Sphendonoid</td>
<td>Hematite (?)</td>
<td>66.50 g</td>
<td>66.62 g</td>
<td>--</td>
</tr>
<tr>
<td>W 38n</td>
<td>W 36</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>67.50 g</td>
<td>67.41 g</td>
<td>--</td>
</tr>
<tr>
<td>W 39n</td>
<td>W 33</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>63.50 g (-)</td>
<td>63.63 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>65.50 g (est.)</td>
<td>68.97 g (cal.)</td>
</tr>
<tr>
<td>W 40n</td>
<td>W 38</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>69.80 g</td>
<td>69.12 g</td>
<td>--</td>
</tr>
<tr>
<td>W 41n</td>
<td>W 41</td>
<td>Domed</td>
<td>Sandstone</td>
<td>76.70 g</td>
<td>73.22 g</td>
<td>--</td>
</tr>
<tr>
<td>W 42n</td>
<td>W 39</td>
<td>Domed</td>
<td>Magnetite</td>
<td>79.30 g</td>
<td>75.67 g</td>
<td>--</td>
</tr>
<tr>
<td>W 43n</td>
<td>W 40</td>
<td>Domed</td>
<td>Magnetite (?)</td>
<td>76.00 g</td>
<td>76.63 g</td>
<td>--</td>
</tr>
<tr>
<td>W 44n</td>
<td>W 37</td>
<td>Irregular</td>
<td>Copper</td>
<td>69.00 g</td>
<td>68.54 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>82.88 g (est.)</td>
<td></td>
</tr>
<tr>
<td>W 45n</td>
<td>W 42</td>
<td>Domed</td>
<td>Hematite</td>
<td>86.00 g</td>
<td>85.97 g</td>
<td>--</td>
</tr>
<tr>
<td>W 46n</td>
<td>W 43</td>
<td>Domed</td>
<td>Hematite (?)</td>
<td>92.00 g</td>
<td>91.05 g</td>
<td>--</td>
</tr>
<tr>
<td>W 47n</td>
<td>W 44</td>
<td>Domed</td>
<td>Hematite</td>
<td>93.20 g</td>
<td>93.11 g</td>
<td>--</td>
</tr>
<tr>
<td>W 48n</td>
<td>W 45</td>
<td>Domed</td>
<td>Hematite</td>
<td>99.60 g</td>
<td>99.31 g</td>
<td>--</td>
</tr>
<tr>
<td>W 49n</td>
<td>W 46</td>
<td>Oblong</td>
<td>Copper</td>
<td>109.50 g</td>
<td>108.15 g (-)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>141.10 g (est.)</td>
<td></td>
</tr>
</tbody>
</table>
Table 23, continued

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>W 50n</td>
<td>W 47</td>
<td>Domed</td>
<td>Hematite</td>
<td>146.40 g</td>
<td>146.23 g</td>
<td>--</td>
</tr>
<tr>
<td>W 51n</td>
<td>W 48</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>177.00 g</td>
<td>175.80 g</td>
<td>--</td>
</tr>
<tr>
<td>W 52n</td>
<td>W 49</td>
<td>Domed</td>
<td>Hematite (?)</td>
<td>185.50 g</td>
<td>184.93 g</td>
<td>--</td>
</tr>
<tr>
<td>W 53n</td>
<td>W 50</td>
<td>Domed</td>
<td>Hematite</td>
<td>188.00 g</td>
<td>187.56 g</td>
<td>--</td>
</tr>
<tr>
<td>W 54n</td>
<td>W 51</td>
<td>Domed</td>
<td>Hematite or Ilmenite</td>
<td>194.00 g</td>
<td>193.06 g</td>
<td>--</td>
</tr>
<tr>
<td>W 55n</td>
<td>W 52</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>204.00 g</td>
<td>202.71 g</td>
<td>--</td>
</tr>
<tr>
<td>W 56n</td>
<td>W 54</td>
<td>Domed</td>
<td>Hematite</td>
<td>244.00 g</td>
<td>240.64 g (-)</td>
<td>246.29 g (cal.)</td>
</tr>
<tr>
<td>W 57n</td>
<td>W 55</td>
<td>Domed</td>
<td>Hematite</td>
<td>279.50 g</td>
<td>278.07 g</td>
<td>--</td>
</tr>
<tr>
<td>W 58n</td>
<td>(W 67)</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>--</td>
<td>281.83 g</td>
<td>--</td>
</tr>
<tr>
<td>W 59n</td>
<td>W 53</td>
<td>Domed</td>
<td>Ilmenite</td>
<td>233.20 g</td>
<td>282.01 g</td>
<td>--</td>
</tr>
<tr>
<td>W 60n</td>
<td>W 56</td>
<td>Sphendonoid</td>
<td>Hematite or Ilmenite</td>
<td>284.50 g</td>
<td>283.59 g</td>
<td>--</td>
</tr>
<tr>
<td>W 61n</td>
<td>W 57</td>
<td>Domed</td>
<td>Hematite</td>
<td>457.00 g</td>
<td>456.91 g</td>
<td>--</td>
</tr>
<tr>
<td>W 62n</td>
<td>W 59</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>470.00 g</td>
<td>460.75 g</td>
<td>--</td>
</tr>
<tr>
<td>W 63n</td>
<td>W 58</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>468.00 g</td>
<td>462.55 g</td>
<td>--</td>
</tr>
<tr>
<td>W 64n</td>
<td>W 60</td>
<td>Sphendonoid</td>
<td>Hematite</td>
<td>501.00 g</td>
<td>499.46 g</td>
<td>--</td>
</tr>
<tr>
<td>W 65n</td>
<td>(W 66)</td>
<td>Discoid</td>
<td>Sandstone</td>
<td>--</td>
<td>872.10 g (-)</td>
<td>--</td>
</tr>
<tr>
<td>W 66n</td>
<td>W 62</td>
<td>Rectangle</td>
<td>Stone</td>
<td>10,500 g</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>W 67n</td>
<td>W 61</td>
<td>Irregular</td>
<td>Stone</td>
<td>73,900 g</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

( ) indicate weights discovered after 1967
As mentioned previously, repeated searches in many dusty museum boxes over a period of a year unfortunately failed to reveal the two missing Gelidonya balance weights (W 5n [W 6] and W 21n [W 19]) for remeasurement and reweighing, though this is how previously unpublished hematite weight W 58n (W 67) was discovered. Additionally, weight W 20n (W 16), which was damaged during recovery, has since become separated from its associated fragments and more searches did not locate them. Consequently, W 20n (W 16)'s mass of 27.32 g, as given in the new catalog, is significantly less than the published mass of 35.00 g. For computation and attribution purposes, the mass values of two of the missing balance weights (W 5n [W 6] and W 12n [W 12]) are those published by Bass (1967: 136), while that of damaged weight piece W 20n (W 16) has been calculated after restoration. But these pieces have been excluded from all statistical calculations aimed at determining their underlying standard unit masses.

In comparing the earlier and recent mass values of the Cape Gelidonya balance weights, it will be noted that there are considerable discrepancies in four instances. For balance weight W 56n (W 54), the 3.36 g decrease is due mostly to the removal of all encrustation from the weight's surface. While this is also the case for W 63n (W 58) and W 62n (W 59), the decreases of 5.45 g and 9.25 g, respectively, are somewhat too great to be explained by that factor alone. This is particularly true of W 62n (W 59), which had few surface deposits. Perhaps the difference is due partly to the retention of water or condensation in some of the deeper pits of these extensively pitted weights during their initial weighing. The greatest difference between the initial and recent mass values, however, occurs in balance weight W 59n (W 53). Neither of the above-mentioned factors could be responsible for this discrepancy, as its new mass of 282.01 g is 49.01 g heavier than its published mass of 233.00 g. The most likely explanation is that an error occurred during the transcription of the handwritten figure, such that the 8 in the weight's original mass of 283.00 g was misread as 3 (the difference between 282.01 g and 283 g being due to additional cleaning), or that a 50-
g balance weight placed in the scale's opposite pan was simply overlooked during the tallying of all the individual weight pieces when the piece was weighed.

Of the 67 objects now cataloged as balance weights or possible balance weights from the Cape Gelidonya shipwreck, five (W 6n [W 5], W 13n [W 7], W 8n [W 8], W 44n [W 37], and W 49n [W 46]) appear to be bronze scraps or pieces of copper ingots (we have since identified three others published as metal, W 11n [W 11], W 16n [W 15], W 30n [W 27], and one as possibly metal, W 14n [W 13], as hematite). All five were cataloged in the final excavation report as “possible weights,” but W 13n (W 7) and W 8n (W 8) were later dismissed as weights by Bass in his analysis because they did not appear to conform to any of the weight standards he ascertained. The remaining three pieces, however, were retained as possible weights. Of these, W 6n (W 5) (10.50 g) was attributed to 1 shekel, W 44n (W 37) (69.00 g) to 6 shekels of 11.50 g, and W 49n (W 46) (109.50 g) to 15 shekels of 7.30 g. With the possible exceptions of W 6n (W 5) and W 49n (W 46), none of these metal pieces show any clear indication of being cast to a certain shape or modified in any way to resemble the balance weight types in the Gelidonya assemblage. Two of them (W 44n [W 37] and W 49n [W 46]) are pocked with large gas holes or pits reminiscent of blister copper, like those on nearly all of the copper ingots from the Cape Gelidonya and Uluburun shipwrecks. It is highly likely, therefore, that at least two of these irregular pieces are fragments of copper ingots. Moreover, W 6n (W 5) appears to be a fragment of some larger object; perhaps it is a portion from the tip of a pick similar to the ones that, along with other scrap tools and implements, were carried in great numbers on the ship. Excavation in 1987 near the boulder, only about 1.5 m east of where W 6n (W 5) was found, revealed many bronze fragments, some of which were not unlike W 6n (W 5) in shape and size. As with pebbles, on the other hand, it is possible that with minor adjustments, bits of metal conforming to a desired mass could have been used as make-do weights for specific weighing applications. Such pieces could have equally served as replacements for missing weights in a set. If these metal
bits from Gelidonya indeed represent balance weights, then they must be included among the group of objects commonly known as "personalized" weights. Any object could have been used by a merchant as a balance weight, the mass value of which was known only to him, hence its name. In the Mediterranean, one still may observe pebbles and cobbles used in markets for weighing low-value commodities. On occasion, I have even observed the use of steel cooking-gas bottles in Turkish markets to weigh heavy produce such as watermelons and pumpkins. The Uluburun ship also yielded many small bits of copper ingot fragments, as well as larger ones. Some of these could have doubled as "personalized" or make-do weights, but they were generally too poorly preserved to be weighed for analysis and assessment.

What the purpose(s) of these bits of metal may have been, if any, now is lost to us. Moreover, because they are copper or bronze, their masses will have been altered through corrosion, rendering them useless for metrological study. For example, the largest of the four metal pieces (W 49n [W 46]) weighs 108.15 g, but with the help of a hydraulic balance and a conservative value of 8.5 g/cm³ for the density of the copper, its original mass may be estimated as at least 141.1 g. In other words, W 49n (W 46) has lost more than 23% of its original mass. These four metal pieces, therefore, have not been included in any analysis or discussion of the Gelidonya weights, but remain in the weight catalog to prevent confusion. Also excluded from all primary analytical studies are damaged, hence underweight, balance weights (W 20n [W 16], W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 56n [W 54]), and the two very large stones (W 65n [W 66] and W 58n [W 67]) cataloged by Bass as possible heavy weights. As noted above, W 5n (W 6) and W 21n (W 19) could not be located in the Bodrum Museum and W 20n (W 16) has lost all of its associated fragments, so they were excluded from our initial statistical analysis involving a quantal search for a common standard unit mass. A subsequent quantal search that incorporated these missing weights, however, did not produce a significantly altered standard unit of mass. The results of additional quantal searches that incorporate the
calculated masses of damaged weights with the masses of intact weights will be discussed below.

Now only 51 of the 67 objects cataloged as balance weights from the Cape Gelidonya shipwreck are helpful in determining the norms, or standard units of mass and their fractionals and multiples, that were carried aboard the ship. It is noteworthy that, with the possible exception of the five copper and/or bronze lumps discussed above, the Gelidonya balance weight assemblage does not include any metal weights, nor lead plugs inserted into the bases of hematite weight pieces for the adjustment of their masses. This absence of metal contrasts with the Uluburun assemblage, in which bronze weights and those with lead plugs are plentiful, and is of great advantage, as it makes a much larger proportion of the weights available for analytical purposes. The Gelidonya assemblage numbers about a hundred fewer weights than does the Uluburun assemblage but nearly 85% of them are usable for statistical purposes. This should permit the determination of the mass standards represented with some certainty.

Aside from the two very large stone objects cataloged by Bass as possible weights, all but four Gelidonya weights are of hematite or related iron ores, all of which are referred to simply as hematite in the text and tables. Definite identifications of the other stone types are not yet available, but a tentative breakdown includes two possibly of dolomitic marl (W 3n [W 3], W 7n [W 64]), and two of sandstone (W 41n [W 41], W 65n [W 66]). One of the two very large stones is probably diorite, the other an unidentified black gneissic stone. Of the 60 pan-balance-sized weights from the wreck, therefore, 93% are of hematite or another iron ore, which is fortunate, as they represent the most durable materials from which ancient balance weights were made. As Bass (1967: 138) notes, possible changes in the masses of the balance weights due to their long submersion in sea water need not be considered, for the polished surfaces that some of them still retain show this to have been negligible. Moreover, as noted above, none of the Gelidonya weights were provided with a lead plug, which were used for the fine adjustment of underweight pieces. That these
balance weights were so exceptionally well crafted as to render adjustment with lead plugs unnecessary cannot be the reason for the absence of plugs, as nearly half of the weights appear to be somewhat haphazardly finished. It is more likely that the owner(s) of these weights, or the circumstances in which they were used, did not require precise mass values, and that the ranges of deviation from the resultant unit-mass were acceptable to the purposes of the owner(s).

As with the Uluburun shipwreck balance weights, the two major shape types in the Cape Gelidonya assemblage are the sphendonoid and the domed and their typological variants, but a few of the weights are difficult to assign to either category. The Cape Gelidonya balance weights, in terms of both their shapes and units, the latter tentatively based on a standard unit mass of approximately 9.3 g (that not all weight pieces conform to this standard will be demonstrated below), may be summarized as follows:

- For the fractional shekel weights (up to ca. 9 g), 1 domed.
- For the unit-shekel weights (9.34-10.19 g), 1 sphendonoid, 2 domed.
- For the 2-shekel weights (18.9-20.48 g), 2 sphendonoid, 1 domed.
- For the 3-shekel weights (25.79-30.43 g), 3 sphendonoids, 3 domed.
- For the 4-shekel weights (35.0-36.19 g), 3 domed.
- For the 5-shekel weights (43.69-51.35 g), 3 sphendonoids, 5 domed, and probably 1 of irregular shape.
- For the 6-shekel weights (53.61-58.79 g), 1 sphendonoid, 4 domed.
- For the 7-shekel weights (63.41-69.12 g), 6 sphendonoids.
- For the 8-shekel weights (73.22-76.63 g), 3 domed.
- For the 10-shekel weights (85.97-99.31 g), 4 domed.
- For the 15-shekel weights (146.23 g), 1 domed.
- For the 20-shekel weights (175.80-202.71 g), 2 sphendonoids, 3 domed.
- For the 25-shekel weight (240.64 g), 1 domed.
- For the 30-shekel weights (278.07-283.59 g), 2 sphendonoids, 2 domed.
- For the 50-shekel (1-mina) weights (456.91-499.46 g), 3 sphendonoids, 1 domed.
- For the 100-shekel (2-mina) weight (872.1 g), 1 domed.

In order to determine the possible weight sets in the Cape Gelidonya assemblage, having first separated them into two major morphological groups, it will prove useful to further divide them into types and sub-types based on physical similarities. The sphendonoid group includes the typical sphendonoid type, whose members are relatively carefully crafted and well polished, and the non-typical sphendonoid type, which exhibits considerable variation in the quality of form and finish. The non-typical sphendonoids consist of 14 weights, of which only W 9n (W 10) is carefully shaped and polished; a second weight (W 58n [W 67]) also reveals considerable craftsmanship in its shaping, but its surface polish is not as extensive as that of W 9n (W 10). The remaining pieces are of somewhat inferior quality, with a few appearing to be only semi-polished or semi-finished products. Moreover, the typical sphendonoids have one surface that is ground flat or virtually so, which serves as the weight's base. While many of the non-typical sphendonoid weights also have a base surface, it is much more roughly fashioned and often somewhat concave. The morphological distinctions between the typical and the non-typical sphendonoids are so evident that separate standards appear to be represented. This, however, is probably not the case, for, as will be seen below, most of the individual pieces fit comfortably within the norm range established for a single standard, although quite a few of them appear to be at the heavier end of this range.

Two sub-types are discernible among the non-typical sphendonoids. A cylindrical shape, with largely or nearly circular sections and somewhat blunt or flat ends, appears to stand out from the oblong weights of bread-loaf shape with more
flattened, ovoid sections and at least one rounded end. The morphological characteristics that distinguish these sub-types are in many instances subtle at best, and some weights show intermediate or even contradictory features.

The domed weight group also includes at least three distinct morphological types and their variants, though not all of them are as clearly definable as are those of the sphendonoid group. These are the truncated spheres, flattened spheres, truncated cones, and "lentoid" weights. Some sugar-loaf-shaped weights and a few roughly angular (pyramidal and cuboid) pieces may yet constitute an additional group.

Distribution of the Weights on the Site

From the object distribution plans of the site, Bass plotted on a single plan the loci of 49 of the 60 stone and metal objects cataloged as weights or possible weights (Bass 1967: 47, fig. 44). An additional weight (W 55n [W 52]) is shown elsewhere in the publication (Bass 1967: 35, fig. 26), bringing to 50 the number of weights with secure provenances. For the remaining 10 objects cataloged as weights but not shown on any site plan, the field catalogs provide the following information. W 4n (W 4) and W 46n (W 43) are from area G and W 12n (W 12) and W 23n (W 22) are probably from G. W 36n (W 34), W 45n (W 42), and W 63n (W 58) were found together in a tight deposit with a copper bun ingot (G106), but the exact location of this deposit in G is not specified. W 28n (W 25) was recovered from an airlift-spoil pile, and no provenance information is available for W 44n (W 37) and W 43n (W 40). No records of any kind have been located for W 58n (W 67), which was found in museum storeroom boxes containing assorted Cape Gelidonya material. The data from the original site plan have been supplemented with the provenances of the four weights discovered between 1987 and 1989 and redrawn as figure 11. The new plan also indicates next to each balance weight number its typological attribution, as defined in this study. For practical considerations these attributions are only loosely applied and
may involve more than one shape, but for the most part they conform to the criteria used to establish the weight sets. These criteria will be discussed below.

Based on the distribution of scarabs, the ship’s lamps, mace heads, whetstones, an astragal, a cylinder seal, weight pieces, and traces of food, Bass (1967: 44-45) concluded that the ship’s stern living quarters, perhaps including a cabin, came to rest on the southeastern side of the site, designated area G. Of the objects cataloged as weights or possible weights, all of them except two (W 55n [W 52] and W 64n [W 60]) almost certainly came from these living quarters. Most of the pieces were found either in area G or in area M, located slightly downslope and to the northeast of G, under a large boulder where many small objects from G seem to have been carried by the current (Bass 1967: 135). Weight W 64n (W 60), the heaviest of the sphendonoids, was found isolated in an undisputed context with a number of bronze tools in area P. This area corresponds to the forward half of the ship and represents the westernmost distribution of artifacts. It is possible that W 64n (W 60) rolled toward the bow of the ship after the bag in which the weights were probably kept or secured opened up, or disintegrated, and released its contents. But because of its isolated position, it also is possible that this weight was kept separate from all the others, a consideration of some importance if this singular piece is to be attributed to a mass standard different from those represented by the other weights. It should be remembered, on the other hand, that although W 55n (W 52) is not on the original weight distribution plan (Bass 1967: 47, fig. 44) it is shown on an excavation phase plan (Bass 1967: 35, fig. 26); it too was found in area P.

The large sandstone disk-shaped weight, W 65n (W 66), recovered during the 1987-1989 surveys of the site, is the easternmost weight found at Cape Gelidonya. It was located with the aid of a metal detector in a depression about 16 m east of the large boulder. Associated with it were bronze fragments, a copper oxhide ingot “handle,” and bits of intrusive material, all of which suggest that this haphazard group of artifacts had been gathered by an octopus to conceal its lair. The recent discoveries
of additional artifacts of ceramic and bronze strewn over the seabed for about 100 m to the east of the site, as well as one of the ship’s stone anchors (found in 1994), suggest that the ship initially tore its bottom on jagged rocks and then drifted westward for some time, taking in water and spilling some of its contents before sinking. While providing considerable information for reconstructing the Cape Gelidonya ship’s demise, the isolated provenance of weight W 65n (W 66) imparts little regarding its relationship to the others weights, except that if this piece had been kept in a bag that held other weights, it would appear that some of them spilled out of the bag before the ship came to rest on the seabed. If this was the case and W 65n (W 66) was not an isolated weight, then one would have to attach less importance to the implications of the weight scatter on the seabed. Perhaps it is only a coincidence, but a similar disk-shaped weight specimen found on the Uluburun shipwreck, although of a lighter mass, also represented the aft-most extent of weights on the site.

The new distribution plan for the Gelidonya weights (fig. 11), although incomplete, shows 55 of the 65 objects cataloged as pan-balance weights. When the weights with known provenances are examined as a whole, some distinct patterns begin to emerge. Most significant for reconstructing the original disposition of the weights on the ship is the concentration of 12 weights at the southernmost section of area G, just upslope of the largest fragment of wood found on the site. This part of G is the highest of any area that yielded weights and lies slightly upslope of the second concentration of weights, just to its north. Therefore, all weights found outside this uppermost deposit must have either rolled downslope from it, or they were stored separately on the ship. Evaluation of the weight distribution reveals that of the six or seven morphological types and sub-types described above, pieces from only four are found here. The truncated spheres, the flattened spheres, and all but one (W 35n [W 32]) of the typical sphenodonoids, on the other hand, are encountered farther down the slope. That virtually all members of these three types slid or rolled down the slope is unlikely. It seems more probable that they were stored separately from the other four,
which, in turn, may have been confined to a single bag, perhaps with multiple pockets, or to several bags stored together. The bag or bags containing the lower weights could also have been stored along with the other bag(s), but the weight distributions make it more likely that the bags, along with their contents, became separated from the other weights during or after the sinking of the ship. It is true that four other weights (W 4n [W 4], W 23n [W 22], W 46n [W 43]) belonging to two of the three types in the lower deposit have loosely specified provenances in area G, though we are fairly safe with W 46n [W 43], which is recorded in the field notebook as coming “probably from hull lump,” the deposit located just downslope of the highest deposit in area G. It is possible, however, that W 4n (W 4) and W 23n (W 22) were found in the uppermost deposit, above the wood.

With regard only to shape, then, we may speculate that it is perhaps not a coincidence that the three morphological types comprising the finest and most handsomely crafted weights are not represented among the 12 weights recovered from upslope of the wood in area G. It seems possible, then, that the finer types, which appear to have been kept together or at least separate from the others, belonged to one person, perhaps a wealthier merchant or some other prominent individual on board, while the more crudely shaped pieces belonged to a lesser merchant or even the indigent smith(s), whose presence on board is hypothesized by Bass based on the smithing tools discovered on the site. Or, perhaps the cruder weights were used for weighing bits of copper, tin, or scrap bronze while the finer pieces were reserved for weighing more valuable commodities.

**Metrological Analysis**

In his study of the weight assemblage from Cape Gelidonya, Bass (1967: 135-47) set aside any preconceived notion of a unit or units, and applied a metrological analysis of his own conception. He divided the masses of the weight pieces by integers and then made a frequency count of the quotients that repeated exactly, and a second
count of those that were within one-tenth of a gram of the numbers that repeated
exactly (Bass 1967: 138, table 1). Bass’s inductive approach prevented from the very
beginning of his analysis any attempt to force the Cape Gelidonya weight specimens
into various standards based on the subjectively determined variations of their
respective unit masses. Quotients that had occurred most frequently are 7.30 g and
9.32 g or 9.33 g. The unit of 7.30 g (found among the Gelidonya weights in multiples
of 4, 5, 6, 8 [?], 9, 15, 20, 28, 32, 64) he identified as the so-called “Phoenician”
standard of 7.32 g, and the unit of 9.32/9.33 g (found among the same weights in
multiples of 1, 3, 6, 7 [?], 10, 19, 25, 25-1/2, 30, 49, and 50 [?]) he identified as the
Egyptian qedet. Based solely on his analysis, Bass established the existence of eight
weight standards and/or their variations among the Gelidonya weights. He concluded
that these weights standards were independent of the seven recurring shapes in his
collection (sphendonoid, domed, sugar-loaf or blunted conical, spherical, cylindrical,
discus-shaped, and irregular). Conversely, Parise (1971), who re-examined the
Gelidonya balance weights, concluded that there was only a single major standard or
system represented, with its unit mass between 59.9 g and 68.4 g. More recently,
Petruso’s (1984, 1985) evaluation of this most interesting set of weights, like Parise,
again revealed only a single major system among the weights represented on the ship,
but one whose standard unit is based on the decimal Egyptian qedet of just under 9.5
g. Bass notes that, even though he kept in mind the statement by Petrie that unlikely
or impractical multiples such as 11, 13, 23, 28, 33, and 46 should not be accepted,
Petrie himself presented some balance weights in these multiples (Petrie 1926: 7), and
on closer examination of the evidence he also had no choice but to accept some such
multiples in his study (Bass 1967: 141).

As ingenious as Bass’s analytical approach may have been, and as much as
subsequent studies and discussions by Parise, Petruso, and others have augmented our
understanding of the Cape Gelidonya weight assemblage, the methodologies may be
characterized as largely intuitive in nature. Recent developments in the field of
metrology now permit analyses that are far more objective than before, and we can therefore proceed with examining the Gelidonya weights with an objective statistical approach using quantal analysis.

As noted earlier, of the 67 objects cataloged as balance weights or possible balance weights from the Cape Gelidonya shipwreck, five (W 6n [W 5], W 13n [W 7], W 8n [W 8], W 44n [W 37], and W 49n [W 46]) have been excluded from our study because their status as balance weights is dubious at best. Additionally, six other weights (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], and W 56n [W 54]) are incomplete and underweight. Although these latter weight specimens almost certainly sustained damage from impact during the sinking of the ship or while they were being recovered, they originally must have been complete, functional balance weights. Therefore all damaged weight pieces have been included in the discussions and their unit attributions have been assigned based on their calculated weights, but for all practical purposes they have been excluded from statistical analyses or computational studies aimed at establishing the standard units in the assemblage. Two weights (W 5n [W 6], W 21n [W 19]) that could not be located for verification of their masses and a third weight (W 20n [W 16]) that has become disassociated from its fragments have also been excluded from our statistical analyses, as have the two stone weights (W 67n [W 61] and W 66n [W 62]) of unusually large size. The remaining 51 pieces, therefore, constitute the population (N=51) of Cape Gelidonya balance weights that may be subjected to quantal searches, using Kendall’s statistic, in order to arrive at a value (or values) that most closely represents the unit standard(s) on which they are based. It should be emphasized once again that the results obtained through Kendall’s statistic are totally independent of biases that might adversely affect recovery of the standard or standards.

Before proceeding with the quantal searches, however, it will prove helpful to first subject these balance weights to a more intuitive analysis in order to establish a tentative standard unit (or units). These results will then be compared with those
revealed by Kendall’s statistic for further corroboration or amendment. Needless to say, in an intuitive analysis involving any group of balance weights, the most important pieces are those that bear incised marks that denote the unit mass of the system or its multiples. This is a most significant consideration, because any quantum produced by Kendall’s statistic will represent a mass that is a common denominator of all elements of a given population of weights, and this may correspond only to a fraction or a multiple of the standard unit mass instead of the standard unit mass itself. Kendall’s statistic alone cannot reveal subjective units, which is the nature of most mass standards, but only isolate the lowest common denominator of the group. This implies, therefore, that a standard unit mass will be equal to or, more likely, a certain multiple of, the common denominator determined by the analysis.

Unfortunately, within the assemblage of balance weights from Cape Gelidonya, only a single weight bears any type of mark. On the top surface of sphendonoid weight W2n (W2), a single stroke is incised perpendicular to the weight’s major axis. It appears to have been made with a sharp, pointed implement. The incision is clearly a denominational mark indicating that the mass of the weight piece corresponds to a single unit of the standard it represents. We are not surprised, therefore, to see that this piece weighs 9.34 g, a mass that corresponds to 1 Ugaritic/Syrian shekel, a standard whose use on the Uluburun ship we have already determined, and which probably was derived from the Egyptian qedet. Bass (1967: 137, 139) also took this balance piece to represent a 1-unit weight of 9.32 g or 9.33 g and attributed it to the Egyptian qedet.

In our attempt to determine intuitively the mass standard or standards represented by the assemblage, then, we cannot overestimate the value of this weight when considering the 60 pieces of hematite or other stones that almost certainly are weights. Assuming that all weight pieces in the assemblage conform to the same standard of ca. 9.3 g, as suggested by weight W2n (W2), the proposed system for the
Cape Gelidonya weights, with their predicted unit attributions and respective resultant unit masses, are given in table 24.

Table 24. Cape Gelidonya weights with their predicted unit attributions and resultant unit masses based on a presumed standard unit mass of ca. 9.3 g.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 1n (W 1)</td>
<td>3.41 g</td>
<td>-</td>
<td>1/3</td>
<td>10.23 g</td>
</tr>
<tr>
<td>2</td>
<td>W 2n (W 2)</td>
<td>9.34 g</td>
<td>1</td>
<td>1</td>
<td>9.34 g</td>
</tr>
<tr>
<td>3</td>
<td>W 3n (W 3)</td>
<td>9.43 g</td>
<td>-</td>
<td>1</td>
<td>9.43 g</td>
</tr>
<tr>
<td>4</td>
<td>W 4n (W 4)</td>
<td>10.19 g</td>
<td>-</td>
<td>1</td>
<td>10.19 g</td>
</tr>
<tr>
<td>5</td>
<td>W 5n (W 6)*</td>
<td>12.30 g</td>
<td>-</td>
<td>1-1/3 (?)</td>
<td>9.22 g</td>
</tr>
<tr>
<td>6</td>
<td>W 7n (W 64)</td>
<td>18.09 g</td>
<td>-</td>
<td>2</td>
<td>9.05 g</td>
</tr>
<tr>
<td>7</td>
<td>W 9n (W 10)</td>
<td>20.48 g</td>
<td>-</td>
<td>2</td>
<td>10.24 g</td>
</tr>
<tr>
<td>8</td>
<td>W 10n (W 9)</td>
<td>20.53 g</td>
<td>-</td>
<td>2</td>
<td>10.27 g</td>
</tr>
<tr>
<td>9</td>
<td>W 11n (W 11)</td>
<td>25.79 g</td>
<td>-</td>
<td>3</td>
<td>8.60 g</td>
</tr>
<tr>
<td>10</td>
<td>W 12n (W 12)</td>
<td>26.05 g</td>
<td>-</td>
<td>3</td>
<td>8.68 g</td>
</tr>
<tr>
<td>11</td>
<td>W 14n (W 13)</td>
<td>27.98 g</td>
<td>-</td>
<td>3</td>
<td>9.33 g</td>
</tr>
<tr>
<td>12</td>
<td>W 15n (W 14)</td>
<td>28.79 g</td>
<td>-</td>
<td>3</td>
<td>9.60 g</td>
</tr>
<tr>
<td>13</td>
<td>W 16n (W 15)</td>
<td>29.42 g</td>
<td>-</td>
<td>3</td>
<td>9.81 g</td>
</tr>
<tr>
<td>14</td>
<td>W 17n (W 65)</td>
<td>30.43 g</td>
<td>-</td>
<td>3</td>
<td>10.14 g</td>
</tr>
<tr>
<td>15</td>
<td>W 18n (W 17)</td>
<td>35.83 g</td>
<td>-</td>
<td>4</td>
<td>8.96 g</td>
</tr>
<tr>
<td>16</td>
<td>W 19n (W 18)</td>
<td>36.19 g (-)</td>
<td>36.77 g (cal.)</td>
<td>4</td>
<td>9.05 g</td>
</tr>
</tbody>
</table>
Table 24, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>W 20n (W 16)</td>
<td>27.32 g ((-))&lt;br&gt;35.00 g (est.)&lt;br&gt;37.04 g (cal.)</td>
<td>--</td>
<td>4</td>
<td>8.75 g</td>
</tr>
<tr>
<td>18</td>
<td>W 21n (W 19)</td>
<td>42.70 g</td>
<td>--</td>
<td>5</td>
<td>8.54 g</td>
</tr>
<tr>
<td>19</td>
<td>W 22n (W 20)</td>
<td>43.69 g</td>
<td>--</td>
<td>5</td>
<td>8.74 g</td>
</tr>
<tr>
<td>20</td>
<td>W 23n (W 22)</td>
<td>44.79 g ((-))&lt;br&gt;45.31 g (cal.)</td>
<td>--</td>
<td>5</td>
<td>9.06 g (cal.)</td>
</tr>
<tr>
<td>21</td>
<td>W 24n (W 21)</td>
<td>45.50 g ((-))&lt;br&gt;47.60 g (cal.)</td>
<td>--</td>
<td>5</td>
<td>9.52 g (cal.)</td>
</tr>
<tr>
<td>22</td>
<td>W 25n (W 23)</td>
<td>47.70 g</td>
<td>--</td>
<td>5</td>
<td>9.54 g</td>
</tr>
<tr>
<td>23</td>
<td>W 26n (W 63)</td>
<td>47.78 g</td>
<td>--</td>
<td>5</td>
<td>9.56 g</td>
</tr>
<tr>
<td>24</td>
<td>W 27n (W 24)</td>
<td>47.95 g</td>
<td>--</td>
<td>5</td>
<td>9.59 g</td>
</tr>
<tr>
<td>25</td>
<td>W 28n (W 25)</td>
<td>49.11 g</td>
<td>--</td>
<td>5</td>
<td>9.82 g</td>
</tr>
<tr>
<td>26</td>
<td>W 29n (W 26)</td>
<td>51.35 g</td>
<td>--</td>
<td>5</td>
<td>10.27 g</td>
</tr>
<tr>
<td>27</td>
<td>W 30n (W 27)</td>
<td>53.61 g</td>
<td>--</td>
<td>6</td>
<td>8.94 g</td>
</tr>
<tr>
<td>28</td>
<td>W 31n (W 28)</td>
<td>53.90 g</td>
<td>--</td>
<td>6</td>
<td>8.98 g</td>
</tr>
<tr>
<td>29</td>
<td>W 32n (W 29)</td>
<td>55.79 g ((-))&lt;br&gt;57.45 g (cal.)</td>
<td>--</td>
<td>6</td>
<td>9.58 g (cal.)</td>
</tr>
<tr>
<td>30</td>
<td>W 33n (W 30)</td>
<td>57.20 g ((-))&lt;br&gt;58.18 g (cal.)</td>
<td>--</td>
<td>6</td>
<td>9.70 g (cal.)</td>
</tr>
<tr>
<td>31</td>
<td>W 34n (W 31)</td>
<td>58.79 g</td>
<td>--</td>
<td>6</td>
<td>9.80 g</td>
</tr>
<tr>
<td>32</td>
<td>W 35n (W 32)</td>
<td>63.41 g</td>
<td>--</td>
<td>7</td>
<td>9.06 g</td>
</tr>
<tr>
<td>33</td>
<td>W 36n (W 34)</td>
<td>65.29 g</td>
<td>--</td>
<td>7</td>
<td>9.33 g</td>
</tr>
<tr>
<td>34</td>
<td>W 37n (W 35)</td>
<td>66.62 g</td>
<td>--</td>
<td>7</td>
<td>9.52 g</td>
</tr>
</tbody>
</table>
Table 24, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>W 38n (W 36)</td>
<td>67.41 g</td>
<td>--</td>
<td>7</td>
<td>9.63 g</td>
</tr>
<tr>
<td>36</td>
<td>W 39n (W 33)</td>
<td>63.63 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>68.97 g (cal.)</td>
<td></td>
<td>7</td>
<td>9.85 g (cal.)</td>
</tr>
<tr>
<td>37</td>
<td>W 40n (W 38)</td>
<td>69.12 g</td>
<td>--</td>
<td>7</td>
<td>9.87 g</td>
</tr>
<tr>
<td>38</td>
<td>W 41n (W 41)</td>
<td>73.22 g</td>
<td>--</td>
<td>8</td>
<td>9.15 g</td>
</tr>
<tr>
<td>39</td>
<td>W 42n (W 39)</td>
<td>75.67 g</td>
<td>--</td>
<td>8</td>
<td>9.46 g</td>
</tr>
<tr>
<td>40</td>
<td>W 43n (W 40)</td>
<td>76.63 g</td>
<td>--</td>
<td>8</td>
<td>9.58 g</td>
</tr>
<tr>
<td>41</td>
<td>W 45n (W 42)</td>
<td>85.97 g</td>
<td>--</td>
<td>10</td>
<td>8.60 g</td>
</tr>
<tr>
<td>42</td>
<td>W 46n (W 43)</td>
<td>91.05 g</td>
<td>--</td>
<td>10</td>
<td>9.11 g</td>
</tr>
<tr>
<td>43</td>
<td>W 47n (W 44)</td>
<td>93.11 g</td>
<td>--</td>
<td>10</td>
<td>9.31 g</td>
</tr>
<tr>
<td>44</td>
<td>W 48n (W 45)</td>
<td>99.31 g</td>
<td>--</td>
<td>10</td>
<td>9.93 g</td>
</tr>
<tr>
<td>45</td>
<td>W 50n (W 47)</td>
<td>146.23 g</td>
<td>--</td>
<td>15</td>
<td>9.75 g</td>
</tr>
<tr>
<td>46</td>
<td>W 51n (W 48)</td>
<td>175.80 g</td>
<td>--</td>
<td>20</td>
<td>8.79 g</td>
</tr>
<tr>
<td>47</td>
<td>W 52n (W 49)</td>
<td>184.93 g</td>
<td>--</td>
<td>20</td>
<td>9.25 g</td>
</tr>
<tr>
<td>48</td>
<td>W 53n (W 50)</td>
<td>187.56 g</td>
<td>--</td>
<td>20</td>
<td>9.38 g</td>
</tr>
<tr>
<td>49</td>
<td>W 54n (W 51)</td>
<td>193.06 g</td>
<td>--</td>
<td>20</td>
<td>9.65 g</td>
</tr>
<tr>
<td>50</td>
<td>W 55n (W 52)</td>
<td>202.71 g</td>
<td>--</td>
<td>20</td>
<td>10.14 g</td>
</tr>
<tr>
<td>51</td>
<td>W 56n (W 54)</td>
<td>240.64 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>246.29 g (cal.)</td>
<td></td>
<td>25</td>
<td>9.85 g (cal.)</td>
</tr>
<tr>
<td>52</td>
<td>W 57n (W 55)</td>
<td>278.07 g</td>
<td>--</td>
<td>30</td>
<td>9.27 g</td>
</tr>
<tr>
<td>53</td>
<td>W 58n (W 67)</td>
<td>281.83 g</td>
<td>--</td>
<td>30</td>
<td>9.39 g</td>
</tr>
<tr>
<td>54</td>
<td>W 59n (W 53)</td>
<td>282.01 g</td>
<td>--</td>
<td>30</td>
<td>9.40 g</td>
</tr>
</tbody>
</table>
Table 24, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>W 60n (W 56)</td>
<td>283.59 g</td>
<td>--</td>
<td>30</td>
<td>9.45 g</td>
</tr>
<tr>
<td>56</td>
<td>W 61n (W 57)</td>
<td>456.91 g</td>
<td>--</td>
<td>50</td>
<td>9.14 g</td>
</tr>
<tr>
<td>57</td>
<td>W 62n (W 59)</td>
<td>460.75 g</td>
<td>--</td>
<td>50</td>
<td>9.22 g</td>
</tr>
<tr>
<td>58</td>
<td>W 63n (W 58)</td>
<td>462.55 g</td>
<td>--</td>
<td>50</td>
<td>9.25 g</td>
</tr>
<tr>
<td>59</td>
<td>W 64n (W 60)</td>
<td>499.46 g</td>
<td>--</td>
<td>50 (?) or 60</td>
<td>9.99 g 8.32 g</td>
</tr>
<tr>
<td>60</td>
<td>W 65n (W 66)</td>
<td>872.10 g</td>
<td>--</td>
<td>100</td>
<td>8.72 g (-)</td>
</tr>
</tbody>
</table>

Gelidonya weight W 64n (W 60), the single largest sphendonoid weight from the Cape Gelidonya and Uluburun shipwrecks, deserves specific consideration. With its mass of 499.46 g, this unusually finely crafted weight is almost certainly a 1-mina weight, though quite heavy when compared to the three other 1-mina weight pieces (W 61n [W 57], W 63n [W 58], W 62n [W 59]) in the assemblage. Moreover, if rated at a mina of 50 shekels of the Syrian standard, then its unit mass of 9.99 g (499.46 ÷ 50) is excessively high. The Mesopotamian mina of 60 shekels, which gives a unit mass of 8.32 g, appears to be far better suited to this specific specimen, as this value is within the range accepted for that standard. Considering the piece’s heavy unit mass as a 50-shekel mina, its unusually well-crafted shape (unique in the Gelidonya assemblage), and that it was found isolated in an area far removed from most other balance weights on the site, the latter suggesting that it was kept separate from the other weights (but note also the nearby find spot of W 55n [W 52]), we prefer to think that W 64n [W 60] represents 60 shekels of 8.32 g.
The data in table 24 may be summarized in graphs that plot the masses of the well-preserved weight pieces against predicted fractions and multiples of 9.3 g. Figure 12 shows plotted weight pieces in the range of 0 to 70 g and in figure 13 are those between 60 and 550 g. Each mark on the diagonals represents the mass of one balance weight. Clearly, most of the Gelidonya balance weights form coherent clusters corresponding to multiples of 9.3 g.

As with the Uluburun weights, it is somewhat surprising to be confronted with the notion that a merchant carrying routine weighing implements did not use weight pieces with marked denominations to simplify his task. It seems that each merchant had to commit his weights to memory in order to correctly and effectively use them. Surely, this situation could be somewhat simplified if we assume within the weight assemblage the presence of several sets, each carried in its own bag or compartment in one bag, so that the merchant had only a limited number of pieces to consider at any given time. Moreover, if each set could be further identified as comprising elements crafted to a certain shape, and preferably from the same material, then the seemingly formidable task of mass mensuration is reduced to manipulating one to two dozen graduated stone weights, with each heavier unit successively larger in size than the one preceding it. Then it is not so complicated to select visually, from two domed weights for example, the next larger or smaller unit. Doing so becomes problematic if the two weights in question are of different shapes, however, as domed and sphendonoid weights of identical mass will be of different sizes. Shape, therefore, is one of the most important criteria by which one may create sets in order to conduct weighing effectively and efficiently. But, for a group of balance weights to serve as a fully functional set, there must be more than just a few weights of similar shape. A complete set should comprise the minimum number of balance weights necessary to efficiently generate, singly and by additive manipulation, all needed values to perform
Fig. 12. Proposed fractional and multiple attributions of the standard unit mass of ca. 9.3 g evident in the Cape Gelidonya balance weights in the range of 0 g to 80 g.
Fig. 13. Proposed multiple attributions of the standard unit mass of ca. 9.3 g evident in the Cape Gelidonya balance weights in the range of 80 g to 500 g.
mass mensuration within the full range represented by the lightest and heaviest pieces in the set. If we establish successfully the mass standards represented by the Gelidonya balance weights, then it will remain to demonstrate that the assemblage contains several different weight sets, each identifiable by shape and complete enough to conveniently meet all weighing needs.

Quantal Search

The foregoing analysis included all of the balance weights from Gelidonya and tested for plausible and logical utilitarian relationships among them. On an intuitive level, there would appear to be strong evidence for a system whose most visible unit is about 9.3 g. On the other hand, I have also speculated about the possible attributions of damaged pieces that do not appear to conform readily to the units specified, by calculating their originally intended masses.

It would seem, therefore, that some of the weight pieces may conform to norms other than that revealed by our intuitive analysis. This is also somewhat evident in figures 2 and 3, where the spread of clusters around some unit attributions are too wide to be considered acceptable. Let us now examine objectively, by means of Kendall's statistic, the population from Cape Gelidonya as presented in table 2, but after excluding those weights that are lost (W 5n [W 6], W 20n [W 16], W 21n [W 19]) and damaged (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 56n [W 54]). According to known mass standards of the Late Bronze Age eastern Mediterranean, all systems and fractions thereof would be included if our quantal analysis covered all values between 2 g and 75 g. By testing the entire Gelidonya balance-weight population for such a wide range of possible standards, without restricting the quantal search to any specific morphological weight type, one should be able to assess objectively which factors, or tested quanta, produce the highest peaks, i.e., values which correspond to the least error terms. Accordingly, the use of Kendall's statistic to conduct a quantal search among the 51 intact weights from
Gelidonya generates the following quanta, presented from the most likely to the least, in table 25. These values are plotted in figure 14.

Table 25. Peak values corresponding to the most likely quanta represented among the 51 intact weights from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.7 g</td>
<td>$\Phi(\tau) = + 2.505$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9.2 g</td>
<td>$\Phi(\tau) = + 2.498$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9.4 g</td>
<td>$\Phi(\tau) = + 2.45$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>25.6 g</td>
<td>$\Phi(\tau) = + 1.988$</td>
<td>1/3 (?) of 76.8 g</td>
</tr>
<tr>
<td>5</td>
<td>23.6 g</td>
<td>$\Phi(\tau) = + 1.906$</td>
<td>1/3 (?) of 70.8 g</td>
</tr>
<tr>
<td>6</td>
<td>23.0 g</td>
<td>$\Phi(\tau) = + 1.730$</td>
<td>1/3 (?) of 69 g</td>
</tr>
<tr>
<td>7</td>
<td>3.2 g</td>
<td>$\Phi(\tau) = + 1.720$</td>
<td>1/3 (?) of 9.6 g</td>
</tr>
<tr>
<td>8</td>
<td>24.1 g</td>
<td>$\Phi(\tau) = + 1.702$</td>
<td>1/3 (?) of 72.3 g</td>
</tr>
<tr>
<td>9</td>
<td>31.0 g</td>
<td>$\Phi(\tau) = + 1.620$</td>
<td>1/2 (?) of 62 g</td>
</tr>
<tr>
<td>10</td>
<td>4.8 g</td>
<td>$\Phi(\tau) = + 1.548$</td>
<td>1/2 (?) of 9.6 g</td>
</tr>
</tbody>
</table>

The highest peak of the quantal search corresponds to a unit of 9.7 g, a value somewhat higher than our intuitive analysis led us to expect, but nevertheless one that almost certainly represents the same mass standard. A second peak, nearly as strong as the first, corresponds to a unit of 9.2 g, and a third peak of 9.4 g follows closely. Plotted values in figure 14 strongly suggest that 9.2 g and 9.4 g are minor spikes on the same peak and, as such, probably can be taken as representing an average value of ca. 9.3 g. The presence of a system whose unit mass is ca. 9.3 g, or 9.32/9.33 g, also
Fig. 14. Plotted results of Kendall's statistic for the 51 intact weights from Cape Gelidonya (i.e., except W 5n [W 6], W 20n [W 16], W 21n [W 19], W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 56n [W 54]).

was suspected by Bass (1967: 138). He submitted that this unit was represented in multiples of 1, 3, 6, 7 (?), 10, 19, 20 (?), 25, 30, 49, 50 (?), and 25 x 1/12, and which he attributed to the *gedet*, or 1/10 of a *deben*, the Egyptian standard. Bass also isolated a unit of 9.5 g that appeared in multiples of 1, 5, 7, 8, 9 (?), 30, and 9 x 1/2 (?). He identified this as a heavier *gedet*, which occurs in Syria, Cyprus, Palestine and Crete. That there appears to be a unit of mass higher than 9.3 g is also revealed by our quantal search, as indicated by the value of 9.7 g. While this unit is somewhat heavier than that proposed by Bass, it does seem to confirm the presence of a unit slightly heavier than 9.3 g. If this is indeed the case, then does the occurrence of such a unit
imply that a shekel of ca. 9.7 g was in use simultaneously with one of ca. 9.3 g? This matter will be discussed further after certain weight sets have been proposed for the Gelidonya assemblage.

The seventh and tenth peaks revealed by the quantal search correspond to 3.2 g and 4.8 g and probably represent 1/3 and 1/2 of 9.6 g, respectively, or approximately the heavy unit of 9.7 g. The fourth, fifth, sixth, and eighth peaks of 25.6 g, 23.6 g, 23 g, and 24.1 g, all essentially of the same order of magnitude, do not readily correspond to any known Near Eastern mass standard or its fractional units. Figure 14 reveals that the last three of these peaks appear to be spikes of the same peak and may be viewed as representing a single value in the vicinity of 23.6 g, which may be taken as corresponding to ca. 2-1/2 units of 9.6 g. These quanta also approximate 1/3 of ca. 69 g to 77 g, masses represented by four balance weights (W 40n [W 38], W42n [W 39], W 43n [W 40], W 41n [W 41]) from Cape Gelidonya.

The slim possibility of the occurrence of an Aegean mass standard of ca. 61 g, as determined by Petruzo (1992), may perhaps be indicated by the ninth peak of 31 g, which is 1/2 of 62 g. Moreover, the sixth and eleventh peaks of 23.0 g and 46.1 g, if they represent 1/3 and 2/3 of ca. 69 g, respectively, may relate to the mass range of the Aegean standard, though they would be somewhat heavy. Parise's (1971: 165, 168, 170) conclusion that nearly all of the Cape Gelidonya weights represent a single system of ca. 65 g corresponding to the Aegean standard, however, is unlikely according to the values of the error terms revealed in our quantal search. With values ranging between +1.497 and +1.620, this unit and its fractionals are quite low in the quantal spectrum and, as such, have a very low probability of representing such a system. We will return to this issue, however.

Based on the error terms of our quantal search for the most likely repeated unit or units, the remaining five systems proposed by Bass for the Cape Gelidonya weight assemblage have a very low or no chance of occurring. The unit of 7.30 g, his so-called Phoenician standard, or what Courtois (1990: 120) calls the Eblite/Paleosyrian
standard, has an error term of -1.1 (but, that this standard may exist among the Gelidonya weights will be discussed below); the necef of 10.30 g has an error term of -0.4; the Hebrew shekel of 11.50 g has an error term of -0.8. These negative (-) error terms indicate that there is no chance these standard units are represented in the Gelidonya weight assemblage. The unit of 10.50 g, which Bass notes as another form of the Palestinian shekel found to range between 10.0 g and 10.5 g, has an error term of +0.058, and the unit of 12.30 g has an error term of +0.27. These values are far too low to represent legitimate standards. Moreover, the peak value in the 10.0-10.5 g range corresponds to a unit of 10.4 g, with an error term of +0.416. According to the magnitudes of the error terms, therefore, the quantum of 10.4 g has a greater chance of occurring as a standard unit than does that of 10.5 g, but the probability of either value occurring is, again, extremely low.

A second quantal search involving all Gelidonya weights, including the calculated masses of the six damaged ones (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 56n [W 54]), but excluding the two lost (W 5n [W 6], W 21n [W 19]) weights and the partially lost weight (W 21n [W 19]), gives us similar results (table 26 and fig. 15). The most likely unit mass of 9.7 g is even more strongly represented, as indicated by its higher error term of +2.789. The second and third quanta have been reversed in rank, but it has already been noted that these are spikes on the same peak such that they can probably be taken to represent an average unit mass of ca. 9.3 g. The remaining quanta, for the most part, are unchanged save for moving up or down a few positions.

The foregoing quantal searches yield the same quantum as the unit mass most likely to be represented in the entire assemblage. But, as stated earlier, we prefer to regard weight piece W 64n (W 60) of 499.46 g as a Mesopotamian mina of 60 shekels of 8.32 g each rather than a Syrian mina of 50 shekels of ca. 9.3 g each. If this interpretation is correct, then W 64n (W 60) should have been excluded from these quantal searches. To discover this weight’s effect on the two previous searches, two
more were conducted without it. Again, the first run includes all intact weights and
the second incorporates the calculated masses of the damaged weights as well (table
27).

Table 26. Peak values corresponding to the most likely quanta represented among the
51 intact and 6 restored (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W
30], W 39n [W 33], W 56n [W 54]) Cape Gelidonya weights.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.7 g</td>
<td>$\Phi (\tau) = +2.789$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9.4 g</td>
<td>$\Phi (\tau) = +2.718$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9.2 g</td>
<td>$\Phi (\tau) = +2.375$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>3.2 g</td>
<td>$\Phi (\tau) = +2.124$</td>
<td>1/3 (? of 9.6 g</td>
</tr>
</tbody>
</table>
| 5        | 25.6 g  | $\Phi (\tau) = +1.803$ | 1/3 (? of 76.8 g
3 of 8.5 g
2 of 12.8 g |
| 6        | 23.6 g  | $\Phi (\tau) = +1.792$ | 1/3 (? of 70.8 g
3 of 7.9 g
2 of 11.8 g |
| 7        | 24.1 g  | $\Phi (\tau) = +1.788$ | 1/3 (? of 72.3 g
3 of 8.0 g
2 of 12.1 g |
| 8        | 23.0 g  | $\Phi (\tau) = +1.757$ | 1/3 (? of 69 g
3 of 7.7 g
2 of 11.5 g |
| 9        | 31.0 g  | $\Phi (\tau) = +1.620$ | 1/2 (? of 62 g
3 of 10.3 g
4 of 7.8 g |
| 10       | 4.8 g   | $\Phi (\tau) = +1.576$ | 1/2 of 9.6 g               |
Fig. 15. Plotted results of Kendall's statistic for the 51 intact and 6 restored weights (W 24n [W 21], W 23n [W 22], W 32n [W 29], W 33n [W 30], W 39n [W 33], W 54n [W 51]) from Cape Gelidonya.

Note that the quantum most likely to represent the standard unit mass for both populations is unchanged at 9.7 g. The quantum of 9.2 g, corresponding to the second highest peak among the intact weights is, again, the same as that obtained for the 51 intact weights (table 25) and is, with a minor shift to third place, also the same as that revealed for the 51 intact and 6 restored weights (table 26). The quantum of 9.4 g observed in tables 25 and 26 has been absorbed by the peak of quantum 9.2 g, which probably may be taken as representing a quantum of ca. 9.3 g. The peak value of 25.6
Table 27. Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) balance weights from Cape Gelidonya, with W 64n (W 60) excluded from each population.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.7 g</td>
<td>$\phi(r) = + 2.729$</td>
<td>1</td>
<td>9.7 g</td>
<td>$\phi(r) = + 2.610$</td>
</tr>
<tr>
<td>2</td>
<td>9.2 g</td>
<td>$\phi(r) = + 2.572$</td>
<td>2</td>
<td>9.4 g</td>
<td>$\phi(r) = + 2.274$</td>
</tr>
<tr>
<td>3</td>
<td>25.6 g</td>
<td>$\phi(r) = + 2.207$</td>
<td>3</td>
<td>9.2 g</td>
<td>$\phi(r) = + 2.229$</td>
</tr>
<tr>
<td>4</td>
<td>23.1 g</td>
<td>$\phi(r) = + 1.880$</td>
<td>4</td>
<td>3.2 g</td>
<td>$\phi(r) = + 2.097$</td>
</tr>
<tr>
<td>5</td>
<td>23.5 g</td>
<td>$\phi(r) = + 1.869$</td>
<td>5</td>
<td>4.4 g</td>
<td>$\phi(r) = + 1.763$</td>
</tr>
<tr>
<td>6</td>
<td>24.2 g</td>
<td>$\phi(r) = + 1.762$</td>
<td>6</td>
<td>11.2 g</td>
<td>$\phi(r) = + 1.616$</td>
</tr>
<tr>
<td>7</td>
<td>3.2 g</td>
<td>$\phi(r) = + 1.568$</td>
<td>7</td>
<td>46.3 g</td>
<td>$\phi(r) = + 1.561$</td>
</tr>
<tr>
<td>8</td>
<td>3.1 g</td>
<td>$\phi(r) = + 1.483$</td>
<td>8</td>
<td>25.6 g</td>
<td>$\phi(r) = + 1.559$</td>
</tr>
<tr>
<td>9</td>
<td>46.2 g</td>
<td>$\phi(r) = + 1.427$</td>
<td>9</td>
<td>23.1 g</td>
<td>$\phi(r) = + 1.544$</td>
</tr>
<tr>
<td>10</td>
<td>4.8 g</td>
<td>$\phi(r) = + 1.375$</td>
<td>10</td>
<td>24.2 g</td>
<td>$\phi(r) = + 1.497$</td>
</tr>
</tbody>
</table>

g, tentatively regarded as representing a 1/3-unit of 76.8 g, now occupies the third rank. This situation is really no different than that presented in table 25, where the quantum of 9.4 g is in third position but has been incorporated into the 9.2 g peak. With regard to the population comprising both intact and restored weights, with W 64n (W 60) excluded (table 27, right) and included (table 26), the quanta are virtually the same and require no significant revision of our earlier interpretation.
The Basic Weight Groups

Having established with relative confidence the predominant standard represented by most weight pieces in the Gelidonya weight assemblage, it now remains to determine if the group comprises any set or sets with enough elements to permit most weighing operations to be performed conveniently. First, however, it should be remembered that this assemblage is probably not as complete as that found on the Uluburun wreck. That this almost certainly is the case is evident from the near absence of pieces representing basic unit fractions. With the single exception of W 1n (W 1) at 3.41 g, no other weight specimen recovered weighs less than 9.34 g. Perhaps the Gelidonya weights were used primarily for weighing bulk or scrap metal instead of more precious commodities such as gold and silver (nothing of which was found during excavation), such that fractional weights were not required. That at least one set had fractional components, however, is revealed by the presence of W 1n (W 1), which most likely would have been complimented at least by 1/2- and 2/3-unit pieces. It is indeed possible that some balance weights, especially smaller pieces, simply were missed during the excavation, as evidenced by the recovery of four examples during visits to the site between 1987 and 1989. The location of one of these weights (W 65n [W 66]), along with the scatter of other artifacts east of the site, makes it clear that the ship tore open its bottom, drifted, and lost some of its contents, including balance weights, before it finally sank, and that some of the fractional weights and others obviously missing from the sets proposed below may have been lost during this time. It also possible, but unlikely, that most of the fractional weights were made of bronze and have corroded completely or at least beyond recognition. Pebbles used for some of the smaller denominations may not have been recognized as such during the excavation. Perhaps future investigations at Cape Gelidonya will produce additional balance weights, but it is highly unlikely that small weights lost between where the ship first stuck the island and its final resting place will ever be recovered. This situation contrasts sharply with that at Uluburun, where the ship settled on the seabed in its
entirety. In this instance, the oversight of excavators or, in the case of small metal weights, destruction by the elements, would primarily account for any missing pieces. Therefore, it is reasonable to assume for Uluburun that nearly all the non-metallic balance weights carried aboard the ship were recovered and that the weight sets proposed in the previous chapter are, for the most part, complete or nearly so.

That the Gelidonya weight assemblage includes elements of several sets is clearly suggested by the much larger than necessary number of weight specimens representing some of the multiple-unit denominations. A case in point is the occurrence of six 3-unit pieces, nine of 5 units, and six 7-unit pieces. In order to facilitate the search for individual weight sets, therefore, we shall begin by separating the Gelidonya weights into two basic morphological groups: the sphendonoid weights and the domed weights. This of course assumes that distinctively fashioned weight pieces can be easily recognized as representing different standards or systems (Petruso 1984: 295). As is true for the Uluburun balance weights, there are intermediary forms that defy facile attribution to either group and whose assignations to one or the other are purely subjective. Weights treated as sphendonoids are not only of the typical sphendonoid shape, but also ovoid, cylindrical, and bread-loaf in appearance. The domed group, on the other hand, includes all weights with circular or nearly circular top view shapes, as well as those that are angular and irregular in form. As such, it comprises truncated spheres, flattened spheres, lentoids, and those that cannot be attributed to any of those three types. This division is in no way meant to suggest that all weights fall neatly into two coherent typological groups based strictly on standardized shapes. The premise behind such a separation is that circular weights may be conveniently separated by sight alone from those that are oblong. After the two major shape groups are identified, it is hoped that more specific morphological types will emerge as elements of easily recognizable working sets.
The Sphenodonoid Weights. The Cape Gelidonya weight assemblage includes 22 weights that may be allotted to the sphenodonoid group. They appear in table 28 as taken from table 24. With the only marked balance weight (W 2n [W 2]) in the assemblage representing a unit weight in this group, we are off to a reasonable start.

Table 28. The sphenodonoid weights from Cape Gelidonya with their unit attributions based on a unit mass of 9.3 g and their resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 2n (W 2)</td>
<td>Hematite</td>
<td>9.34 g</td>
<td>1</td>
<td>1</td>
<td>9.34 g</td>
</tr>
<tr>
<td>2</td>
<td>W 7n (W 64)</td>
<td>Dolomitic marl (?)</td>
<td>18.09 g</td>
<td>--</td>
<td>2</td>
<td>9.05 g</td>
</tr>
<tr>
<td>3</td>
<td>W 9n (W 10)</td>
<td>Hematite</td>
<td>20.48 g</td>
<td>--</td>
<td>2</td>
<td>10.24 g</td>
</tr>
<tr>
<td>4</td>
<td>W 14n (W 13)</td>
<td>Hematite</td>
<td>27.98 g</td>
<td>--</td>
<td>3</td>
<td>9.33 g</td>
</tr>
<tr>
<td>5</td>
<td>W 15n (W 14)</td>
<td>Hematite (?)</td>
<td>28.79 g</td>
<td>--</td>
<td>3</td>
<td>9.60 g</td>
</tr>
<tr>
<td>6</td>
<td>W 17n (W 65)</td>
<td>Hematite</td>
<td>30.43 g</td>
<td>--</td>
<td>3</td>
<td>10.14 g</td>
</tr>
<tr>
<td>7</td>
<td>W 23n (W 22)</td>
<td>Hematite (?)</td>
<td>44.79 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45.31 g (cal.)</td>
<td></td>
<td>5</td>
<td>9.06 g (cal.)</td>
</tr>
<tr>
<td>8</td>
<td>W 24n (W 21)</td>
<td>Hematite</td>
<td>45.50 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47.60 g (cal.)</td>
<td></td>
<td>5</td>
<td>9.52 g (cal.)</td>
</tr>
<tr>
<td>9</td>
<td>W 33n (W 30)</td>
<td>Hematite</td>
<td>57.20 g (-)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>58.18 g (cal.)</td>
<td></td>
<td>6</td>
<td>9.70 g (cal.)</td>
</tr>
<tr>
<td>10</td>
<td>W 35n (W 32)</td>
<td>Magnetite (?)</td>
<td>63.41 g</td>
<td>--</td>
<td>7</td>
<td>9.06 g</td>
</tr>
<tr>
<td>11</td>
<td>W 36n (W 34)</td>
<td>Hematite</td>
<td>65.29 g</td>
<td>--</td>
<td>7</td>
<td>9.33 g</td>
</tr>
<tr>
<td>12</td>
<td>W 37n (W 35)</td>
<td>Hematite (?)</td>
<td>66.62 g</td>
<td>--</td>
<td>7</td>
<td>9.52 g</td>
</tr>
<tr>
<td>13</td>
<td>W 38n (W 36)</td>
<td>Hematite</td>
<td>67.41 g</td>
<td>--</td>
<td>7</td>
<td>9.63 g</td>
</tr>
</tbody>
</table>
Table 28, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>W 39n (W 33)</td>
<td>Hematite</td>
<td>63.63 g (-)</td>
<td>--</td>
<td>--</td>
<td>9.85 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>68.97 g (cal.)</td>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>W 40n (W 38)</td>
<td>Hematite</td>
<td>69.12 g</td>
<td>--</td>
<td>7</td>
<td>9.87 g</td>
</tr>
<tr>
<td>16</td>
<td>W 51n (W 48)</td>
<td>Hematite</td>
<td>175.80 g</td>
<td>--</td>
<td>20</td>
<td>8.79 g</td>
</tr>
<tr>
<td>17</td>
<td>W 55n (W 52)</td>
<td>Hematite</td>
<td>202.71 g</td>
<td>--</td>
<td>20</td>
<td>10.14 g</td>
</tr>
<tr>
<td>18</td>
<td>W 58n (W 67)</td>
<td>Hematite</td>
<td>281.83 g</td>
<td>--</td>
<td>30</td>
<td>9.39 g</td>
</tr>
<tr>
<td>19</td>
<td>W 60n (W 56)</td>
<td>Hematite or Ilmenite</td>
<td>283.59 g</td>
<td>--</td>
<td>30</td>
<td>9.46 g</td>
</tr>
<tr>
<td>20</td>
<td>W 62n (W 59)</td>
<td>Hematite</td>
<td>460.75 g</td>
<td>--</td>
<td>50</td>
<td>9.22 g</td>
</tr>
<tr>
<td>21</td>
<td>W 63n (W 58)</td>
<td>Hematite</td>
<td>462.55 g</td>
<td>--</td>
<td>50</td>
<td>9.25 g</td>
</tr>
<tr>
<td>22</td>
<td>W 64n (W 60)</td>
<td>Hematite</td>
<td>499.46 g</td>
<td>--</td>
<td>50 or 60</td>
<td>9.99 g or 8.32 g</td>
</tr>
</tbody>
</table>

Mean resultant average of intact weights
(i.e., excluding W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33])

9.52 g

Mean resultant average of all weights
(i.e., excluding W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33])

9.52 g

Mean resultant average intact weights except W 64n (W 60)

9.50 g

Mean resultant average of all weights except W 64n (W 60)

9.50 g

Mean resultant weighted average of intact weights

9.48 g

Mean resultant weighted average of all weights

9.49 g

Mean resultant weighted average of intact weights except W 64n (W 60)

9.38 g

Mean resultant weighted average of all weights except W 64n (W 60)

9.39 g
The various averages indicate for the entire sphendonoid group a unit mass value that varies between 9.38 g and 9.52 g. As the weighted average is more likely to represent a value that is closer to the group's intended unit mass, and assuming also that our attribution of W 64n (W60) to the Mesopotamian mina of 60 shekels is correct, then 9.38 g should better reflect the unit mass of the sphendonoids as a whole.

It may now prove helpful to conduct quantal searches among the shape types within the sphendonoid group to determine if there is a shift in the values of the most likely standard units of mass indicated by the first search, which included all of the Cape Gelidonya balance weights (table 26, fig. 15) and those obtained by averaging the resultant unit masses in table 6. Two searches will include first only the 19 intact pieces, then the same pieces with the exclusion of W 64n (W 60). Two more searches will incorporate the calculated masses of the four damaged pieces (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]) into the population, again, with and without W 64n (W 60).

The first sequence of peaks for the ten most likely unit masses within the entire intact sphendonoid group, as revealed by Kendall's statistic, is summarized in table 29 and plotted in figure 16.

As expected, in view of the results of the initial quantal search involving all Gelidonya weights, the tested quanta most likely to be the standard represented in the intact sphendonoid group is one whose unit mass is 9.8 g. Because of the change in population size, the minor shift from 9.7 g in the initial search is to be expected. Therefore, the quanta of 9.7 g and 9.8 g almost certainly correspond to the same unit mass. The error term of the second search, at + 3.156, is much greater than that obtained for the quantum of 9.7 g found for the entire Gelidonya weight group (+ 2.789 in table 26). The relative maxima of the other units have changed somewhat, but the second- and third-place quanta of 9.4 g and 9.6 g in this search probably represent the quanta of 9.2 g and 9.4 g revealed in the initial search, but with their
Table 29. Peak values corresponding to the most likely quanta represented among the 19 intact sphendonoids from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.8 g</td>
<td>$\phi(t) = +3.156$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9.4 g</td>
<td>$\phi(t) = +2.904$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9.6 g</td>
<td>$\phi(t) = +2.813$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>21.9 g</td>
<td>$\phi(t) = +2.701$</td>
<td>$1/3$ (?) of 65.7 g</td>
</tr>
<tr>
<td>5</td>
<td>35.4 g</td>
<td>$\phi(t) = +2.437$</td>
<td>$1/2$ (?) of 70.8 g</td>
</tr>
<tr>
<td>6</td>
<td>16.6 g</td>
<td>$\phi(t) = +2.392$</td>
<td>$1/4$ (?) of 66.4 g</td>
</tr>
<tr>
<td>7</td>
<td>13.5 g</td>
<td>$\phi(t) = +2.222$</td>
<td>$1/5$ (?) of 67.5 g</td>
</tr>
<tr>
<td>8</td>
<td>9.2 g</td>
<td>$\phi(t) = +1.898$</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>15.9 g</td>
<td>$\phi(t) = +1.867$</td>
<td>$1/4$ (?) of 63.6 g</td>
</tr>
<tr>
<td>10</td>
<td>31 g</td>
<td>$\phi(t) = +1.703$</td>
<td>$1/2$ of 62 g</td>
</tr>
</tbody>
</table>

order reversed. As with the initial quantal search, the next three peaks and the subsequent peaks, except for that corresponding to the quantum of 9.2 g, generally denote much higher unit mass values. The quanta of 21.9 g, 35.4 g, 16.6 g, and 13.5 g in the sphendonoid group may be more convincingly interpreted as $1/3$ of 65.7 g, $1/2$ of 70.8 g, $1/4$ of 66.4 g, and $1/5$ of 67.5 g, respectively, than as awkward or unlikely multiples of 9.8 g, 9.4 g, and 9.6 g. As such, they immediately bring to mind the six balance weights (W 35n [W 32], W 39n [W 33], W 36n [W 34], W 37n [W 35], W 38n [W 36], W 40n [W 38]) in the 63.41 - 69.12 g mass range designated as 7-unit pieces, which are unique to the Cape Gelidonya sphendonoid group. By having eliminated the domed weights from the population and submitting only the
Fig. 16. Plotted results of Kendall’s statistic for the 19 intact sphendonoids from Cape Gelidonya.

sphendonoids to a quantal search, therefore, the population now appears to be somewhat biased in favor of a unit mass in the vicinity of that represented by these six weight specimens. As noted earlier, the possible presence of a heavier unit mass of between 65 g and 71 g will be discussed later in this section.

Of interest is the seventh peak, corresponding to a mass of 13.5 g. A standard based on a unit mass of ca. 13.5 g corresponds to the beqa, the Egyptian gold standard. Is it possible that some weights in the sphendonoid group are based on a standard of ca. 9.8 g and others on one of 13.5 g? While this is feasible, weight pieces that may be attributed to a standard unit mass of 13.5 g and its multiples do not give
us a complete set that incorporates the necessary convenient multiples and a sufficient number of elements to perform easy and efficient weighing. In fact, the only weight pieces that may be attributable to such a system are W 14n (W 13), W 15n (W 14), and perhaps W 17n (W 65) (2 units); W 36n (W 34), W 37n (W 35), W 38n (W 36) and W 40n (W 38) (5 units); W 55n (W 52) (15 units); and possibly W 58n (W 67) (ca. 20 units). Most important, of course, is the absence of a weight piece corresponding to a single unit mass. On the other hand, Petrie (1926: 18) noted the relationship between the qedet and the beqa as 4 qedet to 3 beqa, which would largely explain the relationships between some of the Gelidonya qedet weights and the apparent beqa multiples. For example, 3 qedet are approximately 2 beqa, 5 qedet are very roughly 3 beqa, and 7 qedet are about 5 beqa, etc.

A second quantal search including all but one (W 64n [W 60]) of the intact sphendonoids yields nearly identical results (table 30). Note that the third peak of 9.6 g in table 29 is now absorbed by the quantal peak of 9.8 g, which now may be viewed as representing a unit mass of ca. 9.7 g. Another search among the sphendonoids, but now including calculated masses of the four damaged weight pieces (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]), also does not appear to change the overall picture to any great extent (fig. 17 and table 31). The quanta representing the second- and third-highest peaks have reversed their positions so that now 9.6 g ranks second while 9.4 g ranks third. But, this is insignificant as they both probably represent the same standard mass unit.

The importance of the quantal searches involving only the sphendonoid group is that while the relative positions of some of the quanta have shifted, the strongest candidate for the standard unit mass represented is unchanged and still that of the complete weight assemblage: the two peak values, 9.7 g and 9.8 g, can be taken as representing the same unit mass of ca. 9.7 g. The quantal values of 9.4 g and 9.6 g, whose sequence may be reversed depending on the specific population
Table 30. Peak values corresponding to the most likely quanta represented among the 18 intact sphendonoids (i.e., except W 64n [W 60]), from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.8 g</td>
<td>$\phi (\tau) = + 2.917$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9.4 g</td>
<td>$\phi (\tau) = + 2.761$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>22.0 g</td>
<td>$\phi (\tau) = + 2.729$</td>
<td>1/3 (?) of 66 g</td>
</tr>
<tr>
<td>4</td>
<td>16.5 g</td>
<td>$\phi (\tau) = + 2.348$</td>
<td>1/4 (?) of 66 g</td>
</tr>
<tr>
<td>5</td>
<td>35.3 g</td>
<td>$\phi (\tau) = + 2.273$</td>
<td>1/2 (?) of 70.6 g</td>
</tr>
<tr>
<td>6</td>
<td>15.9 g</td>
<td>$\phi (\tau) = + 2.202$</td>
<td>1/4 (?) of 63.6 g</td>
</tr>
<tr>
<td>7</td>
<td>9.2 g</td>
<td>$\phi (\tau) = + 2.031$</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>13.5 g</td>
<td>$\phi (\tau) = + 1.949$</td>
<td>1/5 (?) of 67.5 g</td>
</tr>
<tr>
<td>9</td>
<td>23.1 g</td>
<td>$\phi (\tau) = + 1.796$</td>
<td>1/3 (?) of 69.3 g</td>
</tr>
<tr>
<td>10</td>
<td>30.9 g</td>
<td>$\phi (\tau) = + 1.512$</td>
<td>1/2 (?) of 61.8 g</td>
</tr>
</tbody>
</table>

considered, correspond to the second- and third-highest peaks, respectively. It seems, therefore, that some of the sphendonoids in the group conform to unit masses of 9.4 g and 9.6 g. This may simply indicate that some pieces are on either the lighter or heavier side of the standard unit mass, but equally likely is the presence of some sphendonoids that are purposefully lighter or heavier variants of the same mass standard. In order to effectively investigate the latter possibility, the two weight groups must be divided into smaller sets and their respective standard unit masses determined. With this goal in mind, we shall attempt to divide the Gelidonya sphendonoids into three separate sets.

Before doing so, however, it should be noted that our comparisons will be
incomplete should we fail to conduct one final quantal search within the sphendonoid group—one that excludes weight piece W 64n (W 60), a weight that conforms best to the Mesopotamian mina of 60 shekels of 8.32 g each. Because there seems to be very little difference between the major peaks of populations comprising only the intact sphendonoid weights as opposed to that of all the sphendonoids, as just demonstrated, the final search among the sphendonoids will exclude weight piece W 64n (W 60) but include the four restored pieces (table 32).
Table 31. Peak values corresponding to the most likely quanta represented by the 19 intact and 4 restored sphendonoids (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]) from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.8 g</td>
<td>$\phi(r) = +3.400$</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9.6 g</td>
<td>$\phi(r) = +3.178$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9.4 g</td>
<td>$\phi(r) = +2.993$</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>21.9 g</td>
<td>$\phi(r) = +2.870$</td>
<td>$1/3$ (?) of 65.7 g</td>
</tr>
<tr>
<td>5</td>
<td>16.6 g</td>
<td>$\phi(r) = +2.206$</td>
<td>$1/4$ (?) of 66.4 g</td>
</tr>
<tr>
<td>6</td>
<td>35.4 g</td>
<td>$\phi(r) = +2.091$</td>
<td>$1/2$ (?) of 70.8 g</td>
</tr>
<tr>
<td>7</td>
<td>23.0 g</td>
<td>$\phi(r) = +1.994$</td>
<td>$1/3$ (?) of 69 g</td>
</tr>
<tr>
<td>8</td>
<td>15.9 g</td>
<td>$\phi(r) = +1.851$</td>
<td>$1/4$ (?) of 63.6 g</td>
</tr>
<tr>
<td>9</td>
<td>9.2 g</td>
<td>$\phi(r) = +1.697$</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>13.5 g</td>
<td>$\phi(r) = +1.666$</td>
<td>$1/5$ (?) of 67.5 g</td>
</tr>
</tbody>
</table>

Once again, the quantum of 9.8 g is most likely to represent the standard unit mass of the group. Of significance, however, is the quantum of 22.0 g, which produces the second-highest peak. Comparable to 21.9 g, the value of the fourth-highest peak in the previous two searches, this quantum has now moved up considerably in rank and probably corresponds to $1/3$ of a standard unit mass of 66.0 g. As before, the presence of a unit mass approximating such a value is suggested by the six weights in the range of 63.41 g to 69.12 g. Whether this consideration may be construed as a bivalent property for the sphendonoid group will be discussed below.
Table 32. Peak values corresponding to the most likely quanta represented among the 18 intact (i.e., except W 64n [W 60]) and 4 restored sphendonoids (W 24n [W 21], W 23n [W 22], W 33n [W 30], W 39n [W 33]) from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.8 g</td>
<td>( \phi (\tau) = +3.182 )</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>22.0 g</td>
<td>( \phi (\tau) = +2.918 )</td>
<td>1/3 (?) of 66 g</td>
</tr>
<tr>
<td>3</td>
<td>9.4 g</td>
<td>( \phi (\tau) = +2.859 )</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>23.1 g</td>
<td>( \phi (\tau) = +2.198 )</td>
<td>1/3 (?) of 69.3 g</td>
</tr>
<tr>
<td>5</td>
<td>16.5 g</td>
<td>( \phi (\tau) = +2.174 )</td>
<td>1/4 (?) of 66 g</td>
</tr>
<tr>
<td>6</td>
<td>15.9 g</td>
<td>( \phi (\tau) = +2.149 )</td>
<td>1/4 (?) of 63.6 g</td>
</tr>
<tr>
<td>7</td>
<td>35.3 g</td>
<td>( \phi (\tau) = +1.927 )</td>
<td>1/2 (?) of 70.6 g</td>
</tr>
<tr>
<td>8</td>
<td>9.2 g</td>
<td>( \phi (\tau) = +1.808 )</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>57.6/57.7 g</td>
<td>( \phi (\tau) = +1.648 )</td>
<td>1(?) of 57.7 g</td>
</tr>
<tr>
<td>10</td>
<td>66.6 g</td>
<td>( \phi (\tau) = +1.615 )</td>
<td>1 (?) of 66.6 g</td>
</tr>
</tbody>
</table>

Even a cursory examination of the sphendonoid group immediately reveals three distinct shapes or sub-shapes, namely: the typical sphendonoids, the cylindrical weights, and those roughly resembling bread loaves. The morphological distinctions between the last two, however, are often ambiguous, and some of the pieces among them may just as easily be attributed to one group as the other. Assignable to these three groups are a total of 9 typical sphendonoids and 14 cylindrical and loaf-shaped weights, each of the latter approximately equally represented. The typical sphendonoids, with their likely unit attributions and resultant units, are given in table 33, while the data for the cylindrical and loaf-shaped weights are in table 34.
Table 33. The typical sphendonoids from Cape Gelidonya with their likely unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 2n (W 2)</td>
<td>Hematite</td>
<td>9.34 g</td>
<td>1</td>
<td>9.34 g</td>
</tr>
<tr>
<td>2</td>
<td>W 7n (W 64)</td>
<td>Dolomitic marl (?)</td>
<td>18.09 g</td>
<td>2</td>
<td>9.05 g</td>
</tr>
<tr>
<td>3</td>
<td>W 14n (W 13)</td>
<td>Hematite</td>
<td>27.98 g</td>
<td>3</td>
<td>9.33 g</td>
</tr>
<tr>
<td>4</td>
<td>W 23n (W 22)</td>
<td>Hematite (?)</td>
<td>44.79 g</td>
<td>5</td>
<td>9.06 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45.31 g</td>
<td>(cal.)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>W 35n (W 32)</td>
<td>Magnetite (?)</td>
<td>63.41 g</td>
<td>7</td>
<td>9.06 g</td>
</tr>
<tr>
<td>6</td>
<td>W 37n (W 35)</td>
<td>Hematite (?)</td>
<td>66.62 g</td>
<td>7</td>
<td>9.52 g</td>
</tr>
<tr>
<td>7</td>
<td>W 39n (W 33)</td>
<td>Hematite</td>
<td>63.63 g</td>
<td>7</td>
<td>9.85 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>68.97 g</td>
<td>(cal.)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>W 60n (W 56)</td>
<td>Hematite or Ilmenite</td>
<td>283.59 g</td>
<td>30</td>
<td>9.45 g</td>
</tr>
<tr>
<td>9</td>
<td>W 64n (W 60)</td>
<td>Hematite</td>
<td>499.46 g</td>
<td>50 (?) or 60</td>
<td>9.99 g (8.32 g)</td>
</tr>
</tbody>
</table>

Mean resultant average of intact weights
(i.e., excluding W 23n [W 22], W 39n [W 33])
9.39 g

Mean resultant average of all weights
(i.e., including W 23n [W 22], W 39n [W 33])
9.31 g

Mean resultant average of intact weights except W 64n (W 60)
(and excluding W 23n [W 22], W 39n [W 33])
9.29 g

Mean resultant average of all weights (except W 64n [W 60])
9.33 g

Mean resultant weighted average of intact weights
9.68 g

Mean resultant weighted average of all weights
9.67 g

Mean resultant weighted average of intact weights except W 64n (W 60)
(and excluding W 23n [W 22], W 39n [W 33])
9.41 g

Mean resultant weighted average of all weights except W 64n [W 60]
9.41 g
Table 34. The cylindrical and loaf-shaped weights from Cape Gelidonya with their likely unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 9n (W 10)</td>
<td>Hematite</td>
<td>20.48 g</td>
<td>2</td>
<td>10.24 g</td>
</tr>
<tr>
<td>2</td>
<td>W 15n (W 14)</td>
<td>Hematite (?)</td>
<td>28.79 g</td>
<td>3</td>
<td>9.60 g</td>
</tr>
<tr>
<td>3</td>
<td>W 17n (W 65)</td>
<td>Hematite</td>
<td>30.43 g</td>
<td>3</td>
<td>10.14 g</td>
</tr>
<tr>
<td>4</td>
<td>W 24n (W 21)</td>
<td>Hematite</td>
<td>45.50 g (-)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>47.60 g (cal.)</td>
<td>5</td>
<td>9.52 g (cal.)</td>
</tr>
<tr>
<td>5</td>
<td>W 33n (W 30)</td>
<td>Hematite</td>
<td>57.20 g (-)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>58.18 g (cal.)</td>
<td>6</td>
<td>9.70 g (cal.)</td>
</tr>
<tr>
<td>6</td>
<td>W 36n (W 34)</td>
<td>Hematite</td>
<td>65.29 g</td>
<td>7</td>
<td>9.33 g</td>
</tr>
<tr>
<td>7</td>
<td>W 38n (W 36)</td>
<td>Hematite</td>
<td>67.41 g</td>
<td>7</td>
<td>9.63 g</td>
</tr>
<tr>
<td>8</td>
<td>W 40n (W38)</td>
<td>Hematite</td>
<td>69.12 g</td>
<td>7</td>
<td>9.87 g</td>
</tr>
<tr>
<td>9</td>
<td>W 51n (W 48)</td>
<td>Hematite</td>
<td>175.80 g</td>
<td>20</td>
<td>8.79 g</td>
</tr>
<tr>
<td>10</td>
<td>W 55n (W 52)</td>
<td>Hematite</td>
<td>202.71 g</td>
<td>20</td>
<td>10.14 g</td>
</tr>
<tr>
<td>11</td>
<td>W 58n (W 67)</td>
<td>Hematite</td>
<td>281.83 g</td>
<td>30</td>
<td>9.39 g</td>
</tr>
<tr>
<td>12</td>
<td>W 62n (W 59)</td>
<td>Hematite</td>
<td>460.75 g</td>
<td>50</td>
<td>9.22 g</td>
</tr>
<tr>
<td>13</td>
<td>W 63n (W 58)</td>
<td>Hematite</td>
<td>462.55 g</td>
<td>50</td>
<td>9.25 g</td>
</tr>
</tbody>
</table>

Mean resultant average of intact weights (i.e., excluding W 24n [W 21], W 33n [W 30]) 9.60 g

Mean resultant average of all weights (i.e., including calculated masses of W 24n [W 21], W 33n [W 30]) 9.60 g

Mean resultant weighted average of intact weights 9.39 g

Mean resultant weighted average of all weights 9.40 g
Submitting the intact typical sphendonoids and the intact cylindrical and loaf-shaped weights to independent quantal searches yields 4.5 g (1/2 of 9.0 g) and 9.8 g, respectively, as the most likely standard unit masses for the two groups (fig. 18, table 35). Incorporation of the calculated masses of the two damaged typical sphendonoids (W 23n [W 22], W 39n [W 33]) and of the two damaged pieces assignable to the cylindrical and loaf-shaped weights (W 24n [W 21], W 33n [W 30]) into another series of searches produces identical standard unit masses of 4.5 g and 9.8 g, respectively (fig. 19, table 36).

Fig. 18. Plotted results of Kendall’s statistic for the intact typical sphendonoids from Cape Gelidonya.
Table 35. Peak values corresponding to the most likely quanta represented among only the intact typical sphendonoids, except for W 64n (W 60) (left), and the intact cylindrical and loaf-shaped groups (right), from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.5 g</td>
<td>$\phi (\tau) = + 2.454$</td>
<td>9.8 g</td>
<td>$\phi (\tau) = + 2.645$</td>
</tr>
<tr>
<td>2</td>
<td>9.2 g</td>
<td>$\phi (\tau) = + 2.441$</td>
<td>22.0 g</td>
<td>$\phi (\tau) = + 2.359$</td>
</tr>
<tr>
<td>3</td>
<td>9.4 g</td>
<td>$\phi (\tau) = + 2.420$</td>
<td>16.5 g</td>
<td>$\phi (\tau) = + 2.339$</td>
</tr>
<tr>
<td>4</td>
<td>3.5 g</td>
<td>$\phi (\tau) = + 2.139$</td>
<td>35.3 g</td>
<td>$\phi (\tau) = + 2.207$</td>
</tr>
<tr>
<td>5</td>
<td>4.8 g</td>
<td>$\phi (\tau) = + 1.952$</td>
<td>23.1 g</td>
<td>$\phi (\tau) = + 1.999$</td>
</tr>
<tr>
<td>6</td>
<td>8.9 g</td>
<td>$\phi (\tau) = + 1.686$</td>
<td>25.6 g</td>
<td>$\phi (\tau) = + 1.981$</td>
</tr>
<tr>
<td>7</td>
<td>70.7 g</td>
<td>$\phi (\tau) = + 1.487$</td>
<td>13.5 g</td>
<td>$\phi (\tau) = + 1.961$</td>
</tr>
<tr>
<td>8</td>
<td>9.8 g</td>
<td>$\phi (\tau) = + 1.372$</td>
<td>17.1 g</td>
<td>$\phi (\tau) = + 1.868$</td>
</tr>
<tr>
<td>9</td>
<td>31.6 g</td>
<td>$\phi (\tau) = + 1.348$</td>
<td>15.9 g</td>
<td>$\phi (\tau) = + 1.864$</td>
</tr>
<tr>
<td>10</td>
<td>21.8 g</td>
<td>$\phi (\tau) = + 1.240$</td>
<td>7 g</td>
<td>$\phi (\tau) = + 1.787$</td>
</tr>
</tbody>
</table>

It would seem, then, that based on the results of only quantal searches, these two groups, which were formed solely according to morphological considerations, could represent distinct sets of different unit masses. Do the quanta of 9.0 g to 9.4 g for the typical sphendonoids and 9.8 g for the cylindrical and loaf-shaped group reveal the presence of two distinct weight sets, each deliberately crafted to a different standard unit mass or its variant, or simply sets based on the same mass standard that reflect differing levels of care taken in their production? If the former is true, then it would appear that within the sphendonoid group as a whole, those weights
Fig. 19. Plotted results of Kendall's statistic for all typical sperdonoids from Cape Gelidonya, including restored masses of W 23n (W 22) and W 39n (W 33).

corresponding to a unit mass of 9.8 g are better represented than are those that correspond to a lighter one of ca. 9.3 g. If, on the other hand, a single standard is represented, then it would seem that the non-typical sperdonoids are crudely fashioned pieces that are somewhat heavier than the standard multiples they were intended to represent.

It would appear that the average values following tables 33 and 34 corroborate the latter possibility. The mean resultant average for the intact typical sperdonoids, 9.39 g, and that for the cylindrical and loaf-shaped sperdonoids, 9.60 g, are closer
Table 36. Peak values corresponding to the most likely quanta represented among the typical sphendonoids, including the restored masses of W 23n (W 22) and W 39n (W 33), but excluding W 64n (W 60) (left), and by all cylindrical and loaf-shaped weights, including the restored masses of W 24n (W 21) and W 33n (W 30) (right), from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.5 g</td>
<td>$\phi (r) = +2.348$</td>
<td>9.8 g</td>
<td>$\phi (r) = +3.033$</td>
</tr>
<tr>
<td>2</td>
<td>3.5 g</td>
<td>$\phi (r) = +2.186$</td>
<td>22.0 g</td>
<td>$\phi (r) = +2.147$</td>
</tr>
<tr>
<td>3</td>
<td>9.2 g</td>
<td>$\phi (r) = +2.060$</td>
<td>16.5 g</td>
<td>$\phi (r) = +2.076$</td>
</tr>
<tr>
<td>4</td>
<td>9.4 g</td>
<td>$\phi (r) = +2.049$</td>
<td>25.6 g</td>
<td>$\phi (r) = +2.020$</td>
</tr>
<tr>
<td>5</td>
<td>8.9 g</td>
<td>$\phi (r) = +1.878$</td>
<td>15.9 g</td>
<td>$\phi (r) = +1.899$</td>
</tr>
<tr>
<td>6</td>
<td>21.9 g</td>
<td>$\phi (r) = +1.799$</td>
<td>23.1 g</td>
<td>$\phi (r) = +1.826$</td>
</tr>
<tr>
<td>7</td>
<td>3.0 g</td>
<td>$\phi (r) = +1.505$</td>
<td>28.8 g</td>
<td>$\phi (r) = +1.675$</td>
</tr>
<tr>
<td>8</td>
<td>70.3 g</td>
<td>$\phi (r) = +1.471$</td>
<td>9.4 g</td>
<td>$\phi (r) = +1.631$</td>
</tr>
<tr>
<td>9</td>
<td>8.6 g</td>
<td>$\phi (r) = +1.387$</td>
<td>7.0 g</td>
<td>$\phi (r) = +1.629$</td>
</tr>
<tr>
<td>10</td>
<td>5.7 g</td>
<td>$\phi (r) = +1.380$</td>
<td>24.3 g</td>
<td>$\phi (r) = +1.162$</td>
</tr>
</tbody>
</table>

together in value than are the ca. 9.3 g and 9.8 g quanta revealed by quantal searches of each respective sub-group of weights. Moreover, it is usually the resultant weighted average that is more meaningful in such comparisons. That average for the intact typical sphendonoids (except W 64 [W 60]) is 9.41 g, which is really the same as that for the cylindrical and loaf-shaped sphendonoids (9.40 g). Even if we consider the proposition that for a set consisting of a limited number of elements, a better representation of their intended value may be obtained by averaging the highest and lowest values of the elements in the series than by averaging all the elements, we
obtain for the typical sphendonoids a value of 9.45 g and for the cylindrical and loaf-shaped sphendonoids a value of 9.29 g, again values that are much closer to each other than those revealed by the quantal searches of the sub-groups.

The 7-unit denomination is non-existent in the Uluburun weight assemblage, whereas with six examples, it is the most common multiple among the Gelidonya weights. This is probably the key to our understanding of the operative features of the Gelidonya sphendonoids. The sheer quantity alone suggests the existence of multiple sets, though exactly how many we cannot know for certain. But, assuming that a weight set should be optimally efficient and comprise the minimum number of pieces needed to generate easily all integer mass values by additive combinations, we suggest the presence of at least two and possibly three distinct sphendonoid sets. Because the largest denomination among the group is the mina, or 50-unit weight piece, a decimally configured weight set should consist of elements needed to reproduce, by the addition of various denominations in the set, every integer mass unit between 1 and 50. The decimally configured unit combinations that allow such additive manipulations are given in table 37.

Table 37. Decimally configured sets for generating all integer mass units between 1 and 50.

<table>
<thead>
<tr>
<th>Set No.</th>
<th>Denominations</th>
<th>totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1, 1, 2, 5, 10, 20, 30, 50;</td>
<td>119</td>
</tr>
<tr>
<td>2</td>
<td>1, 2, 2, 5, 10, 20, 30, 50;</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>1, 2, 3, 5, 10, 20, 30, 50;</td>
<td>121</td>
</tr>
</tbody>
</table>
Because the Gelidonya sphendonoids completely lack 10-unit multiples, but do include six specimens of 7-units each, we propose the modified sets shown in table 38, which are also fully capable of replicating every integer mass unit between 1 and 50.

Table 38. Decimally configured sets comprising 7-unit pieces in place of 10-unit pieces for generating all integer mass units between 1 and 50.

<table>
<thead>
<tr>
<th>Set No.</th>
<th>Denominations</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1, 2, 3, 5, 5, 7, 20, 20, 50; total = 113</td>
</tr>
<tr>
<td>5</td>
<td>1, 2, 3, 5, 7, 7, 20, 30, 50; total = 125</td>
</tr>
</tbody>
</table>

As sets 4 and 5 include nine elements each, they are not as efficiently configured as the first three, which comprise only eight elements apiece. Of the two sets proposed in table 38, that the version with two 7-unit pieces was apparently preferred over the one with a single 7-unit piece, could be taken as further evidence for a special meaning attached to these unusual weight pieces. Moreover, the set with two 7-unit pieces would have the advantage of being able to weigh a maximum of 125 units, 12 more than set 4 could weigh.

Keeping in mind the apparent importance of the 7-unit weights, the minimum number of elements needed for a viable set, and the morphological considerations, we propose the following three sets for the Gelidonya sphendonoid group (table 39).

This division into three sets has not been executed arbitrarily. In addition to fulfilling the basic requirement of a set, that is, comprising only as many elements as needed to generate easily all integer mass values between the lowest and highest denominations in the set, we also satisfy the need for distinct shapes that enable the elements of a set to be easily distinguished from those of another. The first set comprises the typical sphendonoids, with flat bases and tapering ends, while the
Table 39. Three sets of weights proposed for the Cape Gelidonya sphendonoids based on morphological considerations.

<table>
<thead>
<tr>
<th>Typical Sphendonoid Weights</th>
<th>Resultant Unit Mass</th>
<th>Cylindrical Sphendonoid Weights</th>
<th>Resultant Unit Mass</th>
<th>Loaf-Shaped Sphendonoid Weights</th>
<th>Resultant Unit Mass</th>
<th>Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 2n (W 2) 9.34 g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>W 7n (W 64) 18.09 g</td>
<td>9.05 g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>W 14n (W 13) 27.98 g</td>
<td>9.33 g</td>
<td>W 15n (W 14) 28.79 g</td>
<td>9.60 g</td>
<td>W 9n (W 10) 20.48 g</td>
<td>10.24 g</td>
<td>3</td>
</tr>
<tr>
<td>W 23n (W 22) 44.79 g (-)</td>
<td>8.96 g (-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>9.06 g (cal.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
<td>W 33n (W 30) 57.20 g</td>
<td>9.53 g (-)</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>58.18 g (cal.)</td>
<td>9.70 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 37n (W 35) 66.62 g</td>
<td>9.52 g</td>
<td>W 35n (W 32) 63.41 g</td>
<td>9.06 g</td>
<td>W 36n (W 34) 65.29 g</td>
<td>9.33 g</td>
<td>7</td>
</tr>
<tr>
<td>W 39n (W 33) 63.63 g (-)</td>
<td>9.09 g (-)</td>
<td>W 40n (W 38) 69.12 g</td>
<td>9.87 g</td>
<td>W 38n (W 36) 67.41 g</td>
<td>9.63 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>68.97 g (cal.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
<td>W 55n (W 52) 202.71 g</td>
<td>10.14 g</td>
<td>W 51n (W 48) 175.80 g</td>
<td>8.79 g</td>
<td>20</td>
</tr>
<tr>
<td>W 60n (W 56) 283.59 g</td>
<td>9.45 g</td>
<td>W 58n (W 67) 281.83 g</td>
<td>9.39 g</td>
<td>---</td>
<td>---</td>
<td>30</td>
</tr>
<tr>
<td>W 64n (W 60) 499.46 g</td>
<td>9.99 g</td>
<td>W 62n (W 59) 460.75 g</td>
<td>9.22 g</td>
<td>W 63n (W 58) 462.55 g</td>
<td>9.25 g</td>
<td>50</td>
</tr>
</tbody>
</table>

**Typical Sphendonoid Weights:**
Mean resultant average of intact weights (without W64n [W 60]) 9.34 g
Mean resultant average of intact weights (with W 64n [W 60]) 9.45 g
Mean resultant average of all weights (without W64n [W 60]) & 9.37 g 
Mean resultant average of all weights (with W64n [W 60]) & 9.45 g 
Mean resultant weighted average of intact weights (without W64n [W 60]) & 9.43 g 
Mean resultant weighted average of intact weights (with W64n [W 60]) & 9.73 g 
Mean resultant weighted average of all weights (without W64n [W 60]) & 9.45 g 
Mean resultant weighted average of all weights (with W64n [W 60]) & 9.71 g 

Cylindrical Sphenoidoid Weights:
Mean resultant average of intact weights & 9.55 g 
Mean resultant average of all weights & 9.57 g 
Mean resultant weighted average of intact weights & 9.46 g 
Mean resultant weighted average of all weights & 9.47 g 

Loaf-Shaped Sphenoidoid Weights:
Mean resultant average of intact weights & 9.56 g 
Mean resultant average of all weights & 9.56 g 
Mean resultant weighted average of intact weights & 9.24 g 
Mean resultant weighted average of all weights & 9.25 g 

second and third sets consist of the cylindrical and loaf-shaped sphenoidoid weights. The cylindrical pieces are largely characterized by essentially circular sections, the loaf-shaped weights by their rectangular to avoid sections. Additionally, the cylindrical weights are mostly fashioned with flat ends, while those of the loaf-shaped weights tend to be rounded, although such differences are not always present. A few pieces exhibit characteristics common to both sets, but for the most part this tripartite scheme seems to work fairly well, and with little practice one can sort all three sets without difficulty.

The cylindrical set has only one 7-unit piece (W 40n [W 38]), but partial compensation for the second one is found in the presence of a 6-unit piece (W 33n [W 30]), a multiple not found in the other two sphenoidoid sets. On the other hand, the typical sphenoidoids include three 7-unit weights, one more than the optimal number needed for the set. Of these three pieces, W 35n (W 32) is an unusually poorly crafted
specimen compared to the others and, morphologically speaking, quite different. Moreover, its provenance on the wreck suggests that it was kept separate from the other typical sphendonoids. In light of these factors we propose the incorporation of W 35n (W 32) into the cylindrical set to complement its single 7-unit piece. Thus all three sphendonoid sets would have a pair of these weight pieces, even though this would render the 6-unit piece (W 33n [W 30]) redundant in the cylindrical sphendonoid set.

Examination of table 39 shows that at least eight denominations are missing, or only six if the 6-unit denomination is excluded. For the typical sphendonoids, they are 6- and 20-unit pieces, and probably a 50-unit or 1-mina weight if we are to accept that W 64n (W 60), with its unit mass of 9.99 g, is too heavy to be comfortably included in this set and better represents a 60-unit mina of an altogether different (Mesopotamian) standard of 8.32 g. W 64n (W 60) is indeed a heavy mass usually not encountered in the sphendonoid shape from the Levant. Among the sphendonoid weights from the Uluburun shipwreck, for example, with possibly a single exception (W 42n [W 39]), the heaviest is a 10-unit piece of 94.65 g. Despite the seemingly limited number of pieces in the typical sphendonoid group from Gelidonya, there are enough to weigh objects of up to at least 500 g. The cylindrical set lacks 1-, 2-, and 5-unit pieces, while the loaf-shaped set needs multiples of 1, 6, and 30. An obvious explanation for the missing pieces, especially with regard to the smaller weights, is that they were overlooked during the excavation or were scattered over the seabed after the ship first struck the submerged rock pinnacle and before it sank. Visits to Cape Gelidonya in recent years have produced four additional weights whose circumstances of discovery substantiate the feasibility of these suppositions.

One obvious way to solve the problem of the missing pieces would be to combine the cylindrical and loaf-shaped weight sets to form a single large set. There is nothing that would prohibit such a merger, as there are no compelling factors necessitating their separation into independent sets in the first place. Such a set
would, however, result in many superfluous 3-, 7-, 20-, and 50-unit multiples. Two
50-unit pieces totaling two minas, on the other hand, would be useful not only for
weighing heavier merchandise, but could also function as a double-mina, a frequently
used standard. Nevertheless, the unnecessary presence of four 7-unit pieces in such a
set argues in favor of separate sets. For the Gelidonya sphendonoids, therefore, three
distinct sets best satisfy the available evidence.

Another factor that favors the presence of three different sets is the easy
recognition of the various denominations by size, because with the exception of W 2n
(W 2), none of the weights are marked in any way to indicate their denominations.
Unless one is intimately familiar with each weight piece, the only way to use them
effectively is with the knowledge that each set comprises a certain number of elements
(eight in this case, not counting the redundant 6-unit piece) and that their sizes are
graduated such that each denomination is physically larger than the one immediately
preceding it. Consequently, for a given set, similar sizes will denote like
denominations. For example, two 7-unit pieces in the same set will be about the same
size. But this will be possible only if the weights have been fashioned from the same
or a similar material and in the same general shape. When the cylindrical and loaf-
shaped sets are united to function as a single set, for example, it becomes extremely
difficult to select like denominations based on size alone, as a 7-unit loaf-shaped
weight is longer than a 7-unit cylindrical piece.

Because the facile recognition of unmarked weight pieces is crucial for
effective weighing, a similar convenience to facilitate conversion and mental tallying
should be evident when using the same weight set for mensuration in a different mass
standard. Given a sufficiently large number of weights, it will usually be possible to
manipulate the individual weight pieces additively to generate with reasonable
accuracy the denominations of most standards. But, unless each weight is clearly
marked to indicate its denomination and its conversion factor to other standards, or
unless the sets are provided with conversion charts that formulate their additive
combinations to obtain the necessary denominations of other standards, a simple
process requiring minimal mental calculation is necessary.

Within the Gelidonya sphendonoid group, therefore, we suggest the existence
of at least two working sets of balance weights. The larger set comprises 14
cylindrical and loaf-shaped weights with a mean resultant average of 9.60 g, while the
second set is made up of eight weights (with W 64n [W 60] excluded) of the typical
sphendonoid shape with a mean resultant average of 9.29 g and a weighted average of
9.41 g. We have proposed a further division of the larger set into two independent
sets based on morphological considerations. All three sets have enough pieces to
generate by additive combination all possible integer values necessary for easy
weighing operations.

It should be stressed at this point that neither the typical sphendonoids nor the
cylindrical and loaf-shaped sets include fractional units. Without these smaller
denominations it is of course impossible to weigh any object with a mass less than the
standard unit, and it seems doubtful that these sets were designed for masses only
within the single and multiple-unit range, especially when there exists a 1/3-unit weight
piece among the domed weights. It is more likely, therefore, that the fractional pieces,
which would have been the smallest weights on the ship, were either overlooked
and/or became dispersed over the large area between where the ship first stuck the
submerged pinnacle of rock near the island and where it eventually sank. This option
certainly is a possibility, especially in the case of smaller weights, as sphendonoid
weight W 7n (W 64), at 18.09 g, was found only during the recent investigative visits
to Cape Gelidonya.

The Domed Weights. The Cape Gelidonya weight assemblage contains 38
weights that are lumped together in the domed group (table 40). One weight (W 21n
[W 19]), now missing, is published in Bass's catalog as an irregular chip of hematite,
and two others (W 11n [W 11], W 16n [W 15]) are more pyramidal or prismatic than
Table 40. Domed weights from Cape Gelidonya with their likely unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No. (Pub. No)</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 1n (W 1)</td>
<td>Limonite</td>
<td>3.41 g</td>
<td>--</td>
<td>1/3</td>
<td>10.23 g</td>
</tr>
<tr>
<td>2</td>
<td>W 3n (W 3)</td>
<td>Marl (?)</td>
<td>9.43 g</td>
<td>--</td>
<td>1</td>
<td>9.43 g</td>
</tr>
<tr>
<td>3</td>
<td>W 4n (W 4)</td>
<td>Hematite</td>
<td>10.19 g</td>
<td>--</td>
<td>1</td>
<td>10.19 g</td>
</tr>
<tr>
<td>4</td>
<td>W 5n (W 6)</td>
<td>Hematite</td>
<td>12.30 g</td>
<td>--</td>
<td>1-1/3</td>
<td>9.2 g</td>
</tr>
<tr>
<td>5</td>
<td>W 10n (W 9)</td>
<td>Hematite</td>
<td>20.53 g</td>
<td>--</td>
<td>2</td>
<td>10.27 g</td>
</tr>
<tr>
<td>6</td>
<td>W 11n (W 11)</td>
<td>Hematite</td>
<td>25.79 g</td>
<td>--</td>
<td>3</td>
<td>8.60 g</td>
</tr>
<tr>
<td>7</td>
<td>W 12n (W 12)</td>
<td>Hematite</td>
<td>26.05 g</td>
<td>--</td>
<td>3</td>
<td>8.68 g</td>
</tr>
<tr>
<td>8</td>
<td>W 16n (W 15)</td>
<td>Hematite</td>
<td>29.42 g</td>
<td>--</td>
<td>3</td>
<td>9.81 g</td>
</tr>
<tr>
<td>9</td>
<td>W 18n (W 17)</td>
<td>Ilmenite (?)</td>
<td>35.83 g</td>
<td>--</td>
<td>4</td>
<td>8.96 g</td>
</tr>
<tr>
<td>10</td>
<td>W 19n (W 18)</td>
<td>Hematite (?)</td>
<td>36.19 g (-)</td>
<td>36.77 g (cal.)</td>
<td>--</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>W 20n (W 16)</td>
<td>Hematite</td>
<td>27.32 g (-)</td>
<td>35.00 g (est.)</td>
<td>37.04 g (cal.)</td>
<td>--</td>
</tr>
<tr>
<td>12</td>
<td>W 21n (W 19)</td>
<td>Hematite</td>
<td>42.70 g</td>
<td>--</td>
<td>5</td>
<td>8.5 g</td>
</tr>
<tr>
<td>13</td>
<td>W 22n (W 20)</td>
<td>Hematite</td>
<td>43.69 g</td>
<td>--</td>
<td>5</td>
<td>8.74 g</td>
</tr>
<tr>
<td>14</td>
<td>W 25n (W 23)</td>
<td>Ilmenite (?)</td>
<td>47.70 g</td>
<td>--</td>
<td>5</td>
<td>9.54 g</td>
</tr>
<tr>
<td>15</td>
<td>W 26n (W 63)</td>
<td>Hematite</td>
<td>47.78 g</td>
<td>--</td>
<td>5</td>
<td>9.56 g</td>
</tr>
<tr>
<td>16</td>
<td>W 27n (W 24)</td>
<td>Hematite</td>
<td>47.95 g</td>
<td>--</td>
<td>5</td>
<td>9.59 g</td>
</tr>
<tr>
<td>17</td>
<td>W 28n (W 25)</td>
<td>Hematite</td>
<td>49.11 g</td>
<td>--</td>
<td>5</td>
<td>9.82 g</td>
</tr>
<tr>
<td>18</td>
<td>W 29n (W 26)</td>
<td>Hematite (?)</td>
<td>51.35 g</td>
<td>--</td>
<td>5</td>
<td>10.27 g</td>
</tr>
<tr>
<td>19</td>
<td>W 30n (W 27)</td>
<td>Hematite</td>
<td>53.61 g</td>
<td>--</td>
<td>6</td>
<td>8.94 g</td>
</tr>
</tbody>
</table>
Table 40, continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Material</th>
<th>Mass</th>
<th>Mark</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>W 30n (W 27)</td>
<td>Hematite</td>
<td>53.61 g</td>
<td>--</td>
<td>6</td>
<td>8.94 g</td>
</tr>
<tr>
<td>20</td>
<td>W 31n (W 28)</td>
<td>Hematite</td>
<td>53.90 g</td>
<td>--</td>
<td>6</td>
<td>8.98 g</td>
</tr>
<tr>
<td>21</td>
<td>W 32n (W 29)</td>
<td>Hematite</td>
<td>55.79 g (–)</td>
<td>--</td>
<td>6</td>
<td>9.58 g (cal.)</td>
</tr>
<tr>
<td>22</td>
<td>W 34n (W 31)</td>
<td>Hematite</td>
<td>58.79 g</td>
<td>--</td>
<td>6</td>
<td>9.80 g</td>
</tr>
<tr>
<td>23</td>
<td>W 41n (W41)</td>
<td>Sandstone</td>
<td>73.22 g</td>
<td>--</td>
<td>8</td>
<td>9.15 g</td>
</tr>
<tr>
<td>24</td>
<td>W 42n (W 39)</td>
<td>Magnetite</td>
<td>75.67 g</td>
<td>--</td>
<td>8</td>
<td>9.46 g</td>
</tr>
<tr>
<td>25</td>
<td>W 43n (W 40)</td>
<td>Magnetite (?)</td>
<td>76.63 g</td>
<td>--</td>
<td>8</td>
<td>9.58 g</td>
</tr>
<tr>
<td>26</td>
<td>W 45n (W 42)</td>
<td>Hematite</td>
<td>85.97 g</td>
<td>--</td>
<td>10</td>
<td>8.60 g</td>
</tr>
<tr>
<td>27</td>
<td>W 46n (W 43)</td>
<td>Hematite (?)</td>
<td>91.05 g</td>
<td>--</td>
<td>10</td>
<td>9.11 g</td>
</tr>
<tr>
<td>28</td>
<td>W 47n (W 44)</td>
<td>Hematite</td>
<td>93.11 g</td>
<td>--</td>
<td>10</td>
<td>9.31 g</td>
</tr>
<tr>
<td>29</td>
<td>W 48n (W 45)</td>
<td>Hematite</td>
<td>99.31 g</td>
<td>--</td>
<td>10</td>
<td>9.93 g</td>
</tr>
<tr>
<td>30</td>
<td>W 50n (W 47)</td>
<td>Hematite</td>
<td>146.23 g</td>
<td>--</td>
<td>15</td>
<td>9.75 g</td>
</tr>
<tr>
<td>31</td>
<td>W 52n (W 49)</td>
<td>Hematite (?)</td>
<td>184.93 g</td>
<td>--</td>
<td>20</td>
<td>9.25 g</td>
</tr>
<tr>
<td>32</td>
<td>W 53n (W 50)</td>
<td>Hematite</td>
<td>187.56 g</td>
<td>--</td>
<td>20</td>
<td>9.38 g</td>
</tr>
<tr>
<td>33</td>
<td>W 54n (W 51)</td>
<td>Hematite or Ilmenite</td>
<td>193.06</td>
<td>--</td>
<td>20</td>
<td>9.65 g</td>
</tr>
<tr>
<td>34</td>
<td>W 56n (W 54)</td>
<td>Hematite</td>
<td>240.64 g (–)</td>
<td>--</td>
<td>25</td>
<td>9.85 g (cal.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>246.29 g (cal.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>W 57n (W 55)</td>
<td>Hematite</td>
<td>278.07 g</td>
<td>--</td>
<td>30</td>
<td>9.27 g</td>
</tr>
<tr>
<td>36</td>
<td>W 59n (W 53*)</td>
<td>Ilmenite</td>
<td>282.01 g</td>
<td>--</td>
<td>30</td>
<td>9.40 g</td>
</tr>
<tr>
<td>37</td>
<td>W 61n (W 57)</td>
<td>Hematite</td>
<td>456.91 g</td>
<td>--</td>
<td>50</td>
<td>9.14 g</td>
</tr>
<tr>
<td>38</td>
<td>W 65n (W 66)</td>
<td>Sandstone</td>
<td>872.10 g (–)</td>
<td>--</td>
<td>100</td>
<td>8.72 g (–)</td>
</tr>
</tbody>
</table>

* incorrectly published as 233.00 g.
Mean resultant average of intact weights 9.37 g
(i.e., excluding missing weights W 5n [W 6], W 18n [W 16],
W 21n [W 19], and damaged weights W 32n [W 29], W 56n [W 54])
Mean resultant average of all weights 9.39 g
(i.e., including calculated masses of W 32n [W 29], W 56n [W 54])
Mean resultant weighted average of intact weights 9.12 g
Mean resultant weighted average of all weights 9.22 g
(i.e., including calculated masses of W 32n [W 29], W 56n [W 54])

domed in appearance. But for practical considerations all have been incorporated into this group.

Using Kendall’s statistic to conduct a quantal search among the intact domed balance weights and a second search that incorporates the calculated masses of the two damaged pieces (W 32n [W 29], W 56n [W 54]) yields a series of maxima quite unlike those obtained for the sphendonoid group. The plot of the error terms \( \phi (\tau) \) against the quanta is given in figure 20 and the values giving the highest peaks are tabulated in descending order in table 41.

The largest weight piece from Gelidonya, W 65n (W 66), although seemingly intact, has been excluded from the initial statistical analysis because it is known to be underweight. Fashioned from a greenish-gray sandstone, its submersion in sea water for more than three millennia seems to have weakened its binding matrix, as it easily loses granules of sand when handled. Even when found, the container it was initially placed in soon held a sizable quantity of sand that had been loosened from its surface. Because this mass loss is uniform over the weight’s surface and does not take the form of chipped areas, the mass loss cannot be quantified. Nevertheless, the exclusion of this seemingly intact weight from all statistical analysis could constitute bias, so a second series of quantal searches, identical to the first but including W 65n (W 66), have also been performed (table 42).
Fig. 20. Plotted results of Kendall's statistic for intact domed weights from Cape Gelidonya (i.e., excluding damaged pieces W 5n [W 6], W 20n [W 16], W 21n [W 19], W 32n [W 29], W 56n [W 54], and underweight W 65n [W 66]).

As is evident in figure 20 and table 41 (left), the highest peak, that is, the quantum yielding the least error, corresponds to 46.4 g, followed by those of 9.3 g, 3.2 g, 23.9 g, and 12.3 g. While the first four peaks may readily be demonstrated to correspond to 5 units of 9.28 g or 1/2 of 92.8 g, 1 unit of 9.3 g, 1/3 of 9.6 g, and 2-1/2 units of 9.56 g or 1/4 of 95.6 g, respectively, the interpretation of the fifth-highest quantum of 12.3 g is not so obvious, though it does match the published mass of domed weight W6, now missing. It also corresponds to ca. 1-1/3 units of 9.22 g or to 7-1/2 shekels of a unit of 92.3 g (7-1/2 x 12.3 g = 92.3), a mass roughly equivalent to
Table 41. Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) domed weights (including restored masses of W 32n [W 29] and W 56n [W 54]) from Cape Gelidonya. W 65n (W66) has been excluded from both populations.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46.4 g</td>
<td>$\phi (\tau) = + 2.648$</td>
<td>46.7 g</td>
<td>$\phi (\tau) = + 2.529$</td>
</tr>
<tr>
<td>2</td>
<td>9.3 g</td>
<td>$\phi (\tau) = + 2.031$</td>
<td>3.2 g</td>
<td>$\phi (\tau) = + 2.364$</td>
</tr>
<tr>
<td>3</td>
<td>3.2 g</td>
<td>$\phi (\tau) = + 1.948$</td>
<td>12.3 g</td>
<td>$\phi (\tau) = + 1.91$</td>
</tr>
<tr>
<td>4</td>
<td>23.9 g</td>
<td>$\phi (\tau) = + 1.922$</td>
<td>9.3 g</td>
<td>$\phi (\tau) = + 1.832$</td>
</tr>
<tr>
<td>5</td>
<td>12.3 g</td>
<td>$\phi (\tau) = + 1.841$</td>
<td>25.3 g</td>
<td>$\phi (\tau) = + 1.654$</td>
</tr>
<tr>
<td>6</td>
<td>25.4 g</td>
<td>$\phi (\tau) = + 1.796$</td>
<td>24.0 g</td>
<td>$\phi (\tau) = + 1.599$</td>
</tr>
<tr>
<td>7</td>
<td>2.6 g</td>
<td>$\phi (\tau) = + 1.403$</td>
<td>23.9 g</td>
<td>$\phi (\tau) = + 1.577$</td>
</tr>
<tr>
<td>8</td>
<td>12.7 g</td>
<td>$\phi (\tau) = + 1.380$</td>
<td>2.6 g</td>
<td>$\phi (\tau) = + 1.527$</td>
</tr>
<tr>
<td>9</td>
<td>9.7 g</td>
<td>$\phi (\tau) = + 1.196$</td>
<td>27.1 g</td>
<td>$\phi (\tau) = + 1.409$</td>
</tr>
<tr>
<td>10</td>
<td>27.0 g</td>
<td>$\phi (\tau) = + 1.075$</td>
<td>4.4 g</td>
<td>$\phi (\tau) = + 1.362$</td>
</tr>
</tbody>
</table>

that of a deben, but both of these values would be unusual and impractical multiples in most any mass standard. Such unwieldy multiples simply cannot be accepted, otherwise one may easily justify virtually all odd multiples and fractions. These results may be more meaningful when compared to a quantal search among a hypothetical set of 18 balance weights conforming to perfectly quantal values of a standard unit mass of 9.3 g (see Appendix A). Examination of the maxima for this hypothetical, perfectly quantal set reveals peaks at values similar to those of the Gelidonya domed weights (table 41), although with somewhat different amplitudes. For example, the peak value
Table 42. Peak values corresponding to the most likely quanta represented among the intact (left) and all (right) domed weights (including restored masses of W 32n [W 29] and W 56n [W 54]) from Cape Gelidonya. W 65n [W 66] has been included in both populations.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>46.1 g</td>
<td>$\Phi(\tau) = +2.781$</td>
<td>46.2 g</td>
<td>$\Phi(\tau) = +2.575$</td>
</tr>
<tr>
<td>2</td>
<td>47.8/47.9 g</td>
<td>$\Phi(\tau) = +2.074$</td>
<td>48.1 g</td>
<td>$\Phi(\tau) = +2.257$</td>
</tr>
<tr>
<td>3</td>
<td>9.3 g</td>
<td>$\Phi(\tau) = +2.037$</td>
<td>3.2 g</td>
<td>$\Phi(\tau) = +2.091$</td>
</tr>
<tr>
<td>4</td>
<td>12.3 g</td>
<td>$\Phi(\tau) = +2.016$</td>
<td>12.3 g</td>
<td>$\Phi(\tau) = +2.08$</td>
</tr>
<tr>
<td>5</td>
<td>23.6 g</td>
<td>$\Phi(\tau) = +1.949$</td>
<td>9.3 g</td>
<td>$\Phi(\tau) = +1.841$</td>
</tr>
<tr>
<td>6</td>
<td>25.6 g</td>
<td>$\Phi(\tau) = +1.857$</td>
<td>24.2 g</td>
<td>$\Phi(\tau) = +1.686$</td>
</tr>
<tr>
<td>7</td>
<td>24.1 g</td>
<td>$\Phi(\tau) = +1.821$</td>
<td>25.6 g</td>
<td>$\Phi(\tau) = +1.634$</td>
</tr>
<tr>
<td>8</td>
<td>3.2 g</td>
<td>$\Phi(\tau) = +1.672$</td>
<td>27.2 g</td>
<td>$\Phi(\tau) = +1.600$</td>
</tr>
<tr>
<td>9</td>
<td>25.0 g</td>
<td>$\Phi(\tau) = +1.506$</td>
<td>25.0 g</td>
<td>$\Phi(\tau) = +1.534$</td>
</tr>
<tr>
<td>10</td>
<td>9.7 g</td>
<td>$\Phi(\tau) = +1.386$</td>
<td>23.6 g</td>
<td>$\Phi(\tau) = +1.445$</td>
</tr>
</tbody>
</table>

of 46.4 g for the domed weights appears to be replicated in the hypothetical set by the third-highest peak in the series, corresponding to a mass of 46.5 g. Similarly, quantal values of 9.3 g, 3.2 g, and 23.9 g among the Gelidonya domed weights are matched in the hypothetical set by the second-, first- (as 3.1 g), and fourth- (as 23.2 g) highest peaks, respectively. While the plotted values of the hypothetical set do not show a peak at 12.3 g, which corresponds to the fifth-highest peak for the domed weights, we do observe two minor peaks at 11.6 g and 13.3 g, in 12th and 16th places, respectively. As with 12.3 g, neither of these two values corresponds to an integer or even a reasonable multiple of the standard unit mass of 9.3 g specified for the
hypothetical set. We may conclude by analogy, therefore, that among the domed weights the fifth-highest peak of 12.3 g need not necessarily correspond to the standard unit mass being sought, nor to its multiples or fractionals. It simply occurs as a common denominator in a population of weights conforming to a standard unit mass in the vicinity of 9.3 g.

When the restored masses of weight pieces W 32n (W 29) and W 56n (W 54) are added to the domed weight population, the results are somewhat similar to those of the intact weights (table 41, right). The quantum yielding the best fit, 46.7 g, comparable in value to that of the previous run, is followed closely by 3.2 g, which has thus moved up one position. More importantly, however, the quantum of 12.3 g is now represented by the third-highest peak, up from fifth position in the previous run. A second pair of quantal searches of the identical populations, but this time including the undervalued mass of W 65n (W 66), again yield similar results, except that 12.3 g occupies fourth position in both the intact and restored weight populations (table 42).

As the value of 12.3 g for the domed weights is obtained directly from Kendall’s statistic, not through examination of evidence of the individual weights, it is possible that it also represents a standard mass unit or its multiple or fractional value. If this value is to correspond to a standard unit mass known to have been in use in the eastern Mediterranean during the Bronze Age, then it can conform only to the Egyptian beqa. It is low, however, just within the limits established empirically for this standard (see Chapter II), but it does not correspond to any other likely or reasonable multiple of the standards attested for the Late Bronze Age eastern Mediterranean, except possibly the Aegean standard, whose unit mass has been established as ca. 61 g by Petruso (1992). If this is the case, the value of 12.3 g may correspond to 1/5 of 61.5 g. One difficulty with this interpretation, however, is that a 1/5 fractional weight of ca. 12.3 g for the Aegean unit is not attested in the corpus of 208 weights studied by Petruso (1992: 78-82). It is in fact precisely the absence of this and other decimal fractions that allows Petruso to postulate a binary base for the Aegean weight
standard. Nor does there appear to be a sufficient number of Cape Gelidonya domed weights attributable to this system to constitute a viable or reasonably functional set, and the few weights that may be attributed to this norm are also good multiples of the standard whose unit mass is ca. 9.3 g.

In his analysis of the Cape Gelidonya weights, Bass proposed the presence of a standard based on a unit mass of 12.3 g, for which he proposed the presence in the assemblage of multiples of 1 (W 5n [W 6]), 4 (W 28n [W 25]), 7 (W 45n [W 42]), and the unlikely 9 x 1/2 (W 31n [W 28]) and 11 x 1/2 (W 38n [W 36]). Of these weights, two each are of domed and sugar-loaf shape, and one is bread-loaf shaped. But, as stated earlier, the combinative manipulation of such a limited number of balance weights does not yield the mass combinations necessary to carry out even the most basic weighing operations. Bass admits that were it not for the well-preserved weight of 12.3 g (W 5n [W 6]), this unit would not have been considered a mass standard at Gelidonya.

The situation with the Gelidonya domed weights is, in fact, rather different from the traditional decimal model proposed by Petruso (1984: 302-03). Because there is a far greater variation in shape among the weights that have been lumped together in the general domed weight group, their attributions are in some instances even more dubious than some of the sphendonoid attributions. Nevertheless, the progression of units clearly transcends that of a simple decimal system comprising only denominations based on 10-unit multiples. Once again, evaluation of the original material combined with the newly discovered domed weights (W 26n [W 63], W 65n [W 66]), and using the 9.3 g unit mass, we obtain the peculiar denominations of 4, 6, and 8 units (table 40).

As with the sphendonoids, the Gelidonya domed weights also comprise far more pieces than are needed for a single set. Clearly, several sets are represented, but how do we best distinguish them? It will be recalled that with six pieces, the 7-unit multiples are by far the best represented denominations in the sphendonoid group. By
assuming that no single set would require more than two pieces of the same
denomination, we tentatively divided the Gelidonya sphendonoids into three sets. This
separation was further assisted by the observation that three basic weight shapes are in
evidence, and that the remaining weights can, for the most part, be conveniently
distributed among the three sets.

With regard to the most common multiples in the Gelidonya domed weight
group, even a cursory examination quickly reveals that there are six 5-unit
denominations. This suggests the presence of at least two (if each had three 5-unit
pieces) and as many as six (if each had one 5-unit piece) separate sets. As with the
sphendonoid weights, however, it would seem more likely that three sets are
represented, each equipped with a pair of 5-unit pieces. Unfortunately, additional
assistance based on morphology is not as readily forthcoming as it is for the
sphendonoids. The difficulty arises not from the lack of variations in shape, but rather
from the abundance; there are a number of pieces that are difficult or almost
impossible to assign to any basic shape group. Even the seemingly distinct
morphological groups are not as coherent as one would wish. In general, however,
the domed weights may be separated into at least three and possibly four main types.
The most characteristic type consists of those weight pieces that are nearly as high as
their diameters with slightly to well-rounded tops and flattened bases (truncated
spheres). Many of these weights also flare out from a small base to a maximum body
diameter at about 2/3 of the height, which gives them the appearance of oblate
truncated spheres with slightly flattened tops.

A quick examination of the truncated-sphere weight pieces reveals pairs of
weights in three of the denominations (5, 10, and 30 units) and three weight specimens
in one denomination (20 units). Such multiplicity is not necessary to generate the
succeeding denominations, but it would of course be helpful in weighing heavier
masses. It is also possible that some pieces are elements of a second set, a suggestion
further reinforced by minor morphological differences between the typical truncated
spheres and those that are more flattened. Accordingly, we propose to further split the truncated spheres into two sets: the truncated spheres and the flattened spheres.

It is clear that neither set is complete. The typical truncated spheres, while including all the necessary denominations heavier than 5 units, lack a 2- or a 3-unit weight piece, if both of the one-unit pieces (W 3n [W 3] and the somewhat heavier W 4n [W 4]) are considered elements of this set. Conversely, if only either W 3n (W 3) or W 4n (W 4) is an element of this set, then two 2-unit pieces or one each of 2-unit and 3-unit pieces are needed to generate all integer multiples between 1 and 5. The same applies to the flattened truncated spheres, which additionally are missing 1-unit pieces, as well as a 50-unit (1 mina) piece that would be needed to bring the weighing capacity up to that of the first set. In the configuration presented, both sets are factored decimally and include no unusual multiples or fractions, as is to be expected for a standard based on a decimal system.

The definition of the second type must be somewhat arbitrary because its elements do not appear to display consistent and distinctive morphological characteristics, but a weak argument may be made for the presence of a dominant shape with rounded top and bottom surfaces and, in some instances, rounded sides as well, i.e., lentoid.

A third potential type consists of weight pieces that are roughly cylindrical with somewhat rounded tops; on some specimens the tops are nearly flat. Most weight pieces in this group also display tops that are narrower than their bases, which gives them the appearance of truncated cones, hence their name as used in this study. Problematic weights not assignable to any other shape type, such as irregular specimens and those of pyramidal or prism form have also been incorporated into this type. It is highly likely that not all weights in this group are elements of the same set, but belong instead to incomplete sets whose other elements have been lost. Because of the morphological similarities shared by some of the elements of the last two types, it is highly likely that some of these sets are factored in the same progression and
based on the same standard unit mass. Therefore, incorrect attributions of some of the elements of each type should not significantly alter the results of subsequent statistical analyses. A fourth potential type consists of weight pieces of the so-called "sugar-loaf" shape, but as there are only a few specimens among the Gelidonya weight assemblage that may be attributed to this type, its status is somewhat dubious and, as such, will not be treated as a separate entity in this study. It also is possible that the discovery of more weight pieces at Cape Gelidonya will facilitate the division of these weights into additional sets. At present, however, we have little choice but to consider the last two types, especially the truncated cones, as basically an assorted collection of odd-shaped pieces that do not conform to the same level of morphological homogeneity of the first type. We submit, then, that the Gelidonya domed weights comprise the four sets presented in table 43. As emphasized before, these attributions are only tentative and have been undertaken primarily to facilitate our understanding of how the weights functioned, not to impose specific set designations based purely on a subjective evaluation of their morphological features.

Table 43. Proposed domed weight sets from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Typical Truncated Sphere</th>
<th>Flattened Truncated Sphere</th>
<th>Lentoid</th>
<th>Truncated Cone</th>
<th>Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 1n (W 1) 3.41 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1/3</td>
</tr>
<tr>
<td>W 3n (W 3) 9.43 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>W 4n (W 4) 10.19 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>W 5n (W 6) 12.30 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1-1/3</td>
</tr>
</tbody>
</table>
Table 43, continued

<table>
<thead>
<tr>
<th>Typical Truncated Sphere</th>
<th>Flattened Truncated Sphere</th>
<th>Lentoid</th>
<th>Truncated Cone</th>
<th>Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>--</td>
<td>W 10n (W 9) 20.53 g</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>W 11n (W 11) 25.79 g</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 12n (W 12) 26.05 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 16n (W 15) 29.42 g</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>W 18n (W 17) 35.83 g</td>
<td>--</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 19n (W 18) 36.19 g (cal.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 20n (W 16) 35.00 g (est. -)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 26n (W 63) 47.78 g</td>
<td>W 25n (W 23) 47.70 g</td>
<td>--</td>
<td>W 22n (W 20) 43.69 g</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 27n (W 24) 47.95 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 28n (W 25) 49.11 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>W 29n (W 26) 51.35 g</td>
<td></td>
</tr>
</tbody>
</table>
Table 43, continued

<table>
<thead>
<tr>
<th>Typical Truncated Sphere</th>
<th>Flattened Truncated Sphere</th>
<th>Lentoid</th>
<th>Truncated Cone</th>
<th>Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>--</td>
<td>--</td>
<td>W32n (W 29) 55.79 g (-) 57.45 g (cal.)</td>
<td>W 30n (W 27) 53.61 g W 31n (W 28) 53.90 g W 34n (W 31) 58.79 g</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W 42n (W 39) 75.67 g W 43n (W 40) 76.63 g</td>
<td>W 41n (W 41) 73.22 g</td>
<td>8</td>
</tr>
<tr>
<td>W 47n (W 44) 93.11 g</td>
<td>W 46n (W 43) 91.05 g</td>
<td>W 48n (W 45) 99.31 g</td>
<td>W 45n (W 42) 85.97 g</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>W 54n (W 51) 193.06 g</td>
<td>W 52n (W 49) 184.93 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>W 53n (W 50) 187.56 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>W 56n (W 54) 240.64 g (-) 246.29 g (cal.)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>W 59n (W 53)* 282.01 g</td>
<td>W 57n (W 55) 278.07 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>W 61n (W 57) 456.91 g</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Incorrectly published as 233.00 g.
Truncated (typical and flattened) weights:
- Mean resultant average of intact weight: 9.42 g
- Mean resultant average of all weights: 9.45 g
- Mean resultant weighted average of intact weights: 9.32 g
- Mean resultant weighted average of all weight: 9.38 g

Petruso (1984: 296, 302) has already suggested that the Gelidonya domed weights are based on a decimal system having a standard unit mass of ca. 9.5 g, and our new study of all the Gelidonya material appears to corroborate many of Petruso's conclusions regarding most of the domed weights, but only those that have been classified as typical and flattened truncated spheres. It is almost certain that the basic mathematical structure of the truncated spheres is decimally configured, but there are peculiarities concerning the other domed weight specimens (lentoids and truncated cones) that are not addressed by Petruso. For example, the re-evaluation of the Gelidonya domed series reveals the presence of a group of weights that appear to correspond to multiples of 4, 6, and 8, which suggests a distinctly binary flavor in their structuring. Exactly how these pieces (4 units: W 18n [W 16], W 19n [W 17], W 20n [W 18]; 6 units: W 30n [W 27], W 31n [W 28], W 32n [W 29], W 34n [W 31]; 8 units: W 42n [W 39], W 43n [W 40], W 41n [W 41]) functioned, for what purpose, if any, they were incorporated within a decimal system, and whether they, along with perhaps some of the 2- and 10-unit weights, represent separate sets based on a binary system, or are directly linked to the regular decimally patterned sets we are proposing, we may never know for certain. The limited number of weights, insufficient multiple units (especially in the heavier range), and the variability of shapes, however, argue against a separate and viable binary set based on morphology alone. Neither is there any significant consistency in the masses of these pieces nor in their calculated unit masses that would warrant special consideration as an independent set by themselves. It seems, therefore, that these unusual units were either integrated somehow with the typical decimally configured domed weights for a special purpose that eludes us at
present, or they constitute elements of unusual denominations of a set(s) based on a standard unit mass other than 9.3 g. More will be said on this subject later.

Of the proposed domed weight sets, that of the truncated spheres is the most uniform in appearance and many of its elements are the most well fashioned specimens in the domed group. Moreover, there are no binary multiples of 4, 6, or 8 among these finely crafted weights. It seems, then, that this is an example of a typical set comprising only decimally configured weights. The set also appears to be complete, with the exception of a 2-unit and/or a 3-unit piece, as there are two 1-unit pieces and a 5-unit piece, which, when used in additive combination, can generate all integers between 1 and 10. It would appear, therefore, that the set includes the following units: 1/3, 1, 1, 1-1/3 (or 1-1/2), 5, 10, 15, 20, 25, 30, and 50. We earlier indicated that the mass of W 59n (W 53) was erroneously published as 233.00 g, hence Petruso's identification as a 25-unit piece. As its correct mass has now been determined to be 282.01 g, it may be assigned to its proper 30-unit designation. On the other hand, W 56n (W 54), with a calculated mass of 246.29 g, is designated as a 25-unit piece (not mentioned by Petruso). It is unusual in that this multiple is not normally found in the weight comparanda of the eastern Mediterranean, even though it is a convenient 1/2 mina of 50 shekels. Though somewhat damaged, its restored mass reveals clearly that it could not have been intended as a 30-unit piece. Weight piece W 50n (W 47) (146.23 g) corresponds to 15 shekels of 9.75 g each. This, again, is an unusual multiple and its unit mass is near the heavier end of the shekel limit; more will be said about this weight below. The one final problematic weight remaining in the set is W 5n (W 6). As this piece could not be located in the Bodrum Museum storerooms for reweighing, its published mass of 12.3 g must suffice. Its spherical shape certainly identifies it as an element of this set, as there are no other weights of this shape from which to assemble yet another set based on a standard unit mass of 12.3 g. How, then, are we to interpret this weight specimen, which corresponds to 1-1/3 units of 9.25 g or perhaps to a light and somewhat unlikely 1-1/2-unit multiple of a standard with a unit
mass of 8.2 g? Both of these denominations are impractical and unusual for a decimal set, but a weight of 12.3 g does correspond to the unit mass of the beqa, as noted earlier. If there is any validity to this association, then perhaps the domed sets are not only conventional sets based on decimally factored multiples of a unit mass of ca. 9.3 g, but also sets that incorporate 4-, 6-, and 8-unit binary multiples corresponding to integer multiples of a second standard with a unit mass of 12.3 g. One difficulty with this interpretation is that, if there is something to be said for the morphological integrity of a set, then the truncated sphere set includes only a single 1-unit weight piece based on the 12.3 g unit mass, and no multiples of 4, 6, and 8 in that shape, which also would be needed to make it a viable bivalent set. There is an extra 6-unit piece (W 30n [W 27]) among the Gelidonya assemblage that could be allotted to this set, but its morphology does not fit the rest of the set comfortably. This 6-unit piece is somewhat crudely crafted and, along with other similarly crafted 4- and 8-unit pieces, it has been assigned to the lentoid set. It could be that these weight pieces are later additions to the truncated sphere set that facilitated conversion to a bivalent series and thereby expanded the set's range to include the beqa standard. By such a procedure, the standard truncated spheres may have been modified to meet new needs for bivalent sets, in keeping with the sphendonoid sets on the ship. The truncated spheres, with their decimally configured denominations and theoretical masses based on a standard unit mass of 9.3 g, and their possible denominations based on a standard unit mass of 12.3 g, appear in table 44.

Even though only one of the proposed Gelidonya domed sets appears in the preceding table, the correspondence of the fractional and multiple units of the ca. 9.3-g and 12.3-g standard unit masses would be similar for all Gelidonya domed sets. While the presence of bivalent sets cannot be proven, the fairly close approximation of the theoretical masses for both standard units, as shown in table 44, especially at the lighter end of the scale, is noteworthy. It should be stressed, however, that much of the correspondence between the values results directly from the known 3:4 ratio.
Table 44. The truncated-sphere domed weights from Cape Gelidonya with unit attributions based on theoretical standard unit masses of 9.3 g and 12.3 g.

<table>
<thead>
<tr>
<th>Truncated Spheres</th>
<th>Unit Mass of 9.3 g</th>
<th>Unit Mass of 12.3 g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass</td>
<td>Unit</td>
</tr>
<tr>
<td>W 1n (W 1) (3.41 g)</td>
<td>1/3</td>
<td>3.1 g</td>
</tr>
<tr>
<td>W 3n (W 3) (9.43 g)</td>
<td>1</td>
<td>9.3 g</td>
</tr>
<tr>
<td>W 4n (W 4) (10.19 g)</td>
<td>1</td>
<td>9.3 g</td>
</tr>
<tr>
<td>W 5n (W 6) (12.30 g)</td>
<td>1-1/3</td>
<td>12.4 g</td>
</tr>
<tr>
<td>--</td>
<td>4</td>
<td>37.2 g</td>
</tr>
<tr>
<td>W 26n (W 63) (47.78 g)</td>
<td>5</td>
<td>46.5 g</td>
</tr>
<tr>
<td>--</td>
<td>6</td>
<td>55.8 g</td>
</tr>
<tr>
<td>--</td>
<td>8</td>
<td>74.4 g</td>
</tr>
<tr>
<td>W 47n (W 44) (93.11 g)</td>
<td>10</td>
<td>93.0 g</td>
</tr>
<tr>
<td>W 50n (W 47) (146.23 g)</td>
<td>15</td>
<td>139.5 g</td>
</tr>
<tr>
<td>W 54n (W 51) (193.06 g)</td>
<td>20</td>
<td>186.0 g</td>
</tr>
<tr>
<td>W 56n (W 54) (240.64 g) - (246.29 g) cal.</td>
<td>25</td>
<td>232.5 g</td>
</tr>
<tr>
<td>W 59n (W 53) (282.01 g)</td>
<td>30</td>
<td>279.0 g</td>
</tr>
<tr>
<td>W 61n (W 57) (456.91 g)</td>
<td>50</td>
<td>465 g</td>
</tr>
</tbody>
</table>
between the beqa and the qedet. But some of these equivalent multiples may never have been used or needed in the beqa standard. The 1-, 3-, 6-, 12-, and 15-unit theoretical masses for 12.3 g fit the actual masses fairly well (except that the 3- and 6-unit pieces do not exist in the actual set), and correspond to 1-1/3- (or a heavy 1-1/2-), 4-, 8-, 15-, and 20-unit multiples of 9.3 g. While 15-, and 25-unit pieces of 9.3 g do not appear to be out of place in a decimal set, they are seldom, if ever, used. The 4-, 6- and 8-unit pieces, on the other hand, are virtually unknown in sets based on decimal progression. Until a better explanation is advanced, therefore, the occurrence of the unusual 4-, 6-, and 8-unit multiples in a decimal set, and to a lesser extent, the 15- and 25-unit multiples, may be explained by the theory of bivalence.

One multiple that is difficult to interpret is that of 6 units, which averages ca. 55.9 g for the four domed weights (W 30n [W 27], W 31n [W 28], W 32n [W 29], W 34n [W 31]) in this mass range (table 43). This value roughly corresponds to a 5-unit multiple of 12.3 g, as table 44 shows, but the last weight is about 10% more than the average mass of the pieces. Moreover, a 5-unit multiple of the beqa was not normally used, though it may have been included in this instance to facilitate conversion to a decimal progression. It should be noted also that while the mass values of the 18-, 24-, and 36-unit multiples of the 12.3 g standard are well within 10% of, respectively, the 25-, 30-, and 50-unit multiples of the 9.3 g standard, there appears to be no conclusive evidence for the occurrence of such multiples in the beqa system. Nor do these multiples correlate all that satisfactorily with the actual mass values of the weights. But, this is perhaps to be expected when unit conversions are involved. The correlations may have been sufficient for the uses to which these weights were put.

We cannot claim to have reasonably accounted for all the unusual multiples found among the Gelidonya domed weights. The provocative bivalence hypothesis does seem to provide an explanation for most of the multiples that would be odd or impractical in a decimally factored 9.3-g set, so until additional research discredits this
view or produces an alternative interpretation, it will remain a possible explanation for
the design of these peculiarly configured balance weight pieces.

Petruso (1984: 302-03, ill. 9) selected for his analysis only nine of the weights
cataloged by Bass as dome shaped. These weights, along with their published and
recently measured masses, appear in table 45. Submitting these published and current
masses to independent quantal searches using Kendall’s statistic yields the data
tabulated in table 46.

Table 45. The nine Cape Gelidonya weights cataloged by Bass as dome shaped, with
unit attributions suggested by Petruso.

<table>
<thead>
<tr>
<th>No.</th>
<th>Cat. No.</th>
<th>Published Mass</th>
<th>Actual Mass</th>
<th>Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W 25n (W 23)</td>
<td>47.70 g</td>
<td>47.70 g</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>W 46n (W 43)</td>
<td>92.00 g</td>
<td>91.05 g</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>W 47n (W 44)</td>
<td>93.20 g</td>
<td>93.11 g</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>W 50n (W 47)</td>
<td>146.40 g</td>
<td>146.23 g</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>W 52n (W 49)</td>
<td>185.50 g</td>
<td>184.93 g</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>W 53n (W 50)</td>
<td>188.00 g</td>
<td>187.56 g</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>W 59n (W 53)</td>
<td>233.20 g</td>
<td>282.01 g</td>
<td>25/30</td>
</tr>
<tr>
<td>8</td>
<td>W 57n (W 55)</td>
<td>279.50 g</td>
<td>278.07 g</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>W 61n (W 57)</td>
<td>457.00 g</td>
<td>456.91 g</td>
<td>50</td>
</tr>
</tbody>
</table>

It seems Petruso was correct in his assertion that the decimally factored
Gelidonya weights are based on a standard unit mass of 9.3 g. The quantum of 11.7 g,
with the second-least error term, however, follows closely, while the quanta of 10.4 g
and 13.4 g occupy the distant third and fourth ranks, respectively. A second quantal search of the same population, but using their recently measured masses, however, produces notable changes in rank. The first position is now occupied by 13.4 g with 11.7 g a close second. The quantum of 9.3 g, the value that yielded the least error in

Table 46. Peak values corresponding to the most likely quanta represented among the nine Cape Gelidonya weights cataloged by Bass as dome shaped and used in Petruso's analysis, with published masses (left) and actual masses (right).

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.3 g</td>
<td>$\Phi(r) = + 2.874$</td>
<td>13.4 g</td>
<td>$\Phi(r) = + 2.002$</td>
</tr>
<tr>
<td>2</td>
<td>11.7 g</td>
<td>$\Phi(r) = + 2.637$</td>
<td>11.7 g</td>
<td>$\Phi(r) = + 1.991$</td>
</tr>
<tr>
<td>3</td>
<td>10.4 g</td>
<td>$\Phi(r) = + 1.787$</td>
<td>9.3 g</td>
<td>$\Phi(r) = + 1.915$</td>
</tr>
<tr>
<td>4</td>
<td>13.4 g</td>
<td>$\Phi(r) = + 1.782$</td>
<td>10.4 g</td>
<td>$\Phi(r) = + 1.798$</td>
</tr>
<tr>
<td>5</td>
<td>7.8 g</td>
<td>$\Phi(r) = + 1.623$</td>
<td>2.4 g</td>
<td>$\Phi(r) = + 1.543$</td>
</tr>
<tr>
<td>6</td>
<td>6.1 g</td>
<td>$\Phi(r) = + 1.564$</td>
<td>4.7 g</td>
<td>$\Phi(r) = + 1.425$</td>
</tr>
<tr>
<td>7</td>
<td>5.8 g</td>
<td>$\Phi(r) = + 1.421$</td>
<td>4.4 g</td>
<td>$\Phi(r) = + 1.327$</td>
</tr>
<tr>
<td>8</td>
<td>6.7 g</td>
<td>$\Phi(r) = + 1.322$</td>
<td>6.6 g</td>
<td>$\Phi(r) = + 1.206$</td>
</tr>
<tr>
<td>9</td>
<td>5.2 g</td>
<td>$\Phi(r) = + 1.306$</td>
<td>7.7 g</td>
<td>$\Phi(r) = + 1.184$</td>
</tr>
<tr>
<td>10</td>
<td>3.2 g</td>
<td>$\Phi(r) = + 1.287$</td>
<td>14.7 g</td>
<td>$\Phi(r) = + 1.008$</td>
</tr>
</tbody>
</table>

the previous run, now ranks third. It is clear that a major change in the mass of a single element in the population (W 59n [W 53]), has caused a significant shift in the quanta, as the one that initially gave the least error later gives the third-least error. A
quantal run without W 59n (W 53) (not shown), however, restores the quantum of 9.3 g to first place.

By adding to Petruso's domed set those morphologically suitable denominations smaller than 5 units (W 3n [W 3], W 4n [W 4], and the recently discovered W 26n [W 63]), a 20 unit-piece (W 54n [W 51]) not included by Petruso, a 25-unit piece (W 56n [W 54]) omitted from the original list because it was described by Bass as spherical rather than dome shaped, and by eliminating W 50n (W 47), designated as a 15-unit piece by Petruso, we find the following weights in the proposed typical and flattened truncated sphere sets: W 1n (W 1), W 3n (W 3), W 4n (W 4), W 25n (W 23), W 26n (W 63), W 46n (W 43), W 47n (W 44), W 52n (W 49), W 53n (W 50), W 54n (W 51), W 56n (W 54), W 59n (W 53), W 57n (W 55), and W 61n (W 57). This set is not so different from the one with which Petruso demonstrated the decimal factoring of the Gelidonya domed weights based on a standard unit mass of ca. 9.3 g. Consequently, we may reasonably expect Kendall's statistic to yield ca. 9.3 g as the standard unit mass for this population of weights as well. As revealed in table 47, however, the quantum with the least error corresponds to 11.7 g while 9.3 g comes in a somewhat close second. It will be recalled that in Petruso's original set, the situation was reversed, with 9.3 g ranking first and 11.7 g a close second. Although superficial scrutiny of table 45 (i.e., omitting a quantal search) appears to indicate that this particular weight group conforms relatively well to a standard based on unit mass of ca. 9.3 g, it is somewhat surprising that this quantum does not yield an overwhelmingly positive error term, and that the quantal value of 11.7 g very closely follows the most likely quantum in the first instance (table 46) and far exceeds it in the second (table 47).

How, then, may we explain the quantum of 11.7 g? Of the mass standards used in the eastern Mediterranean, one whose upper and lower limits have been determined as approximately 11-12 g, and which is proposed as the standard used in Asia Minor, appears to bracket 11.7 g. Could the truncated spheres from the Cape
Gelidonya shipwreck represent a set of balance weights conforming to this mass standard? And if so, was there on the Gelidonya ship a truly viable set comprising the necessary denominations to conduct weight mensuration according to this standard? Table 48 lists the unit attribution of each truncated sphere weight based on a standard unit mass of 11.7 g and its resultant unit mass based on the actual mass.

Table 47. Peak values corresponding to the most likely quanta represented among the thirteen domed Cape Gelidonya weights proposed to be elements of the truncated sphere set.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.7 g</td>
<td>$\Phi(\tau) = +2.774$</td>
<td>1 (?)</td>
</tr>
<tr>
<td>2</td>
<td>9.3 g</td>
<td>$\Phi(\tau) = +2.259$</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>4.4 g</td>
<td>$\Phi(\tau) = +2.068$</td>
<td>1/2 (?) of 8.8 g</td>
</tr>
<tr>
<td>4</td>
<td>4.8 g</td>
<td>$\Phi(\tau) = +1.868$</td>
<td>1/2 (?) of 9.6 g</td>
</tr>
<tr>
<td>5</td>
<td>3.2 g</td>
<td>$\Phi(\tau) = +1.818$</td>
<td>1/3 of 9.6 g</td>
</tr>
<tr>
<td>6</td>
<td>9.7 g</td>
<td>$\Phi(\tau) = +1.478$</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>10.3 g</td>
<td>$\Phi(\tau) = +1.449$</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>2.5 g</td>
<td>$\Phi(\tau) = +1.383$</td>
<td>1/4 (?) of 10 g or 1/3 (?) of 7.5 g</td>
</tr>
<tr>
<td>9</td>
<td>7.7 g</td>
<td>$\Phi(\tau) = +1.333$</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>2.8 g</td>
<td>$\Phi(\tau) = +1.286$</td>
<td>1/4 (?) of 11.2 g</td>
</tr>
</tbody>
</table>

The multiples of this standard seem to be derived by doubling. However, not only are the odd 21- and 39-unit multiples impractical, hence unlikely denominations, they cannot be generated by doubling, nor are there any integer denominations smaller
than 4 to allow the weighing of smaller quantities (of course perhaps not all weights have been recovered from the site). When viewed as a whole, then, a set of weights based on a standard unit mass of 11.7 g does not seem viable for the Gelidonya assemblage.

Yet all the weights in table 48, except W 56n (W 54), do correspond extremely well to a unit mass of ca. 9.3 g (cf. table 44, left). Moreover, all the weight pieces

Table 48. Unit attributions of the Cape Gelidonya typical- and flattened-truncated sphere weights based on a standard unit mass of 11.7 g.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Unit Attribution</th>
<th>Theoretical Mass (attribution x 11.7 g)</th>
<th>Actual Mass</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 3n (W 3)</td>
<td>3/4</td>
<td>8.8 g</td>
<td>9.43 g</td>
<td>12.57 g</td>
</tr>
<tr>
<td>W 4n (W 4)</td>
<td></td>
<td>10.19 g</td>
<td>13.59 g</td>
<td></td>
</tr>
<tr>
<td>W 25n (W 23)</td>
<td>4</td>
<td>46.8 g</td>
<td>47.70 g</td>
<td>11.93 g</td>
</tr>
<tr>
<td>W 26n (W 63)</td>
<td></td>
<td>47.78 g</td>
<td>11.95 g</td>
<td></td>
</tr>
<tr>
<td>W 46n (W 43)</td>
<td>8</td>
<td>93.6 g</td>
<td>91.05 g</td>
<td>11.38 g</td>
</tr>
<tr>
<td>W 47n (W 44)</td>
<td></td>
<td>93.11 g</td>
<td>11.64 g</td>
<td></td>
</tr>
<tr>
<td>W 52n (W 49)</td>
<td>16</td>
<td>187.2 g</td>
<td>184.93 g</td>
<td>11.56 g</td>
</tr>
<tr>
<td>W 53n (W 50)</td>
<td></td>
<td>187.56 g</td>
<td>11.72 g</td>
<td></td>
</tr>
<tr>
<td>W 54n (W 51)</td>
<td></td>
<td>193.06 g</td>
<td>12.07 g</td>
<td></td>
</tr>
<tr>
<td>W 56n (W 54)</td>
<td>21</td>
<td>245.7 g</td>
<td>240.64 g (-)</td>
<td>11.73 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>246.29 g (cal.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W 57n (W 55)</td>
<td>24</td>
<td>280.8 g</td>
<td>278.07 g</td>
<td>11.59 g</td>
</tr>
<tr>
<td>W 59n (W 53)</td>
<td></td>
<td>282.01 g</td>
<td>11.75 g</td>
<td></td>
</tr>
<tr>
<td>W 61n (W 57)</td>
<td>39</td>
<td>456.3 g</td>
<td>456.91 g</td>
<td>11.72 g</td>
</tr>
</tbody>
</table>
except W 56n (W 54) conform to decimally factored multiples commonly found in the corpus of Near Eastern weights. W 56n (W 54) is an unexpected 25-unit multiple that, with its restored mass of 246.29 g, could represent a somewhat heavy shekel of 9.85 g. Although weight piece W 59n (W 53), with its incorrectly published mass, was also identified as a 25-unit piece by Petruso, we now know this is not the case. Therefore, W 56n (W 54) represents the only weight of this denomination in the Gelidonya assemblage. There are no 25-unit multiples reported among the more than 600 weight pieces recovered from Ras Shamra/Ugarit (Courtois 1990: 122). A 25-unit piece, however, does correspond to 1/2 of a mina and, as such, appears to be a conveniently factored mass. Although parallels are lacking, we may have to accept W 56n (W 54) as a 25-unit weight piece in the 9.3-g standard until it is proven otherwise.

On the other hand, interpretation of W 50n (W 47), which at 146.23 g corresponds to a 15-unit multiple detected and published as such by Petruso, is more problematic. Although this is a decimally factored multiple, it is not a very useful weight piece to have in a set, nor does it correspond to any reasonable fraction of the mina. There are certainly no parallels for it at Ras Shamra/Ugarit, and it is not really of the typical truncated-sphere shape, even though it is uniformly crafted and well finished in the manner of the elements of that type. For these reasons W 50n (W 47) has been removed from the assemblage and incorporated into another set, discussed below.

It is evident from table 40 and figures 12 and 13 that some of the domed weight pieces lie either outside or are only marginally within the acceptable upper and lower limits for the standard unit mass of ca. 9.3 g. As such, they are mostly too low or too high to be considered acceptable pieces of a set based on this unit mass. Having demonstrated with some confidence that the typical- and flattened-truncated spheres represent decimally factored sets based on a unit mass of ca. 9.3 g, it now remains to investigate the underlying structure of the remaining 20 weight pieces of non-truncated sphere types incorporated into the domed group. It may be of interest,
therefore, to evaluate these remaining weights as a group by conducting a quantal search to determine whether the most likely quantum revealed for the group as a whole, is repeated when the weights are divided into their respective types (i.e., lentoid, truncated cone).

The results of the two quantal searches for the non-truncated spheres, one incorporating only the intact specimens (left), and the other including also the calculated masses of damaged specimens (i.e., W 20n [W 16], W 19n [W 18], W 32n [W 29]; right) are given in table 49.

Table 49. Peak values corresponding to the most likely quanta among only the intact non-truncated (left), and all non-truncated (right) weight pieces from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.3 g</td>
<td>$\phi (\tau) = +1.892$</td>
<td>12.3 g</td>
<td>$\phi (\tau) = +1.994$</td>
</tr>
<tr>
<td>2</td>
<td>12.4 g</td>
<td>$\phi (\tau) = +1.703$</td>
<td>3.3 g</td>
<td>$\phi (\tau) = +1.727$</td>
</tr>
<tr>
<td>3</td>
<td>8.6 g</td>
<td>$\phi (\tau) = +1.428$</td>
<td>2.6 g</td>
<td>$\phi (\tau) = +1.594$</td>
</tr>
<tr>
<td>4</td>
<td>2.7 g</td>
<td>$\phi (\tau) = +1.411$</td>
<td>5.4 g</td>
<td>$\phi (\tau) = +1.395$</td>
</tr>
<tr>
<td>5</td>
<td>5.4 g</td>
<td>$\phi (\tau) = +1.391$</td>
<td>4.5 g</td>
<td>$\phi (\tau) = +1.381$</td>
</tr>
<tr>
<td>6</td>
<td>5.0 g</td>
<td>$\phi (\tau) = +1.281$</td>
<td>9.2 g</td>
<td>$\phi (\tau) = +1.308$</td>
</tr>
<tr>
<td>7</td>
<td>4.3 g</td>
<td>$\phi (\tau) = +1.277$</td>
<td>7.3 g</td>
<td>$\phi (\tau) = +1.269$</td>
</tr>
<tr>
<td>8</td>
<td>4.5 g</td>
<td>$\phi (\tau) = +1.258$</td>
<td>4.1 g</td>
<td>$\phi (\tau) = +1.215$</td>
</tr>
<tr>
<td>9</td>
<td>6.6 g</td>
<td>$\phi (\tau) = +0.978$</td>
<td>3.6 g</td>
<td>$\phi (\tau) = +1.038$</td>
</tr>
<tr>
<td>10</td>
<td>14.5 g</td>
<td>$\phi (\tau) = +0.880$</td>
<td>8.6 g</td>
<td>$\phi (\tau) = +1.021$</td>
</tr>
</tbody>
</table>
It may be noted readily from table 49 that the first two quantal values of 3.3 g and 12.4 g for the intact pieces, and 12.3 g and 3.3 g for all pieces, are approximately the same values except for the reversal in their ranking. It seems, then, that unit masses of 12.3 g/12.4 g, and 9.9 g (3 x 3.3 g) satisfy the 20 pieces of non-sphendonoid weights from Cape Gelidonya with the least amount of error. This result, in fact, is not significantly different from those obtained for the entire domed-weight assemblage, as given on tables 41 and 42. There, however, the quantal searches were conducted over a much broader spectrum of 2 g to 75 g, as compared to the present search involving a range of only 2 g to 15 g. Disregarding on tables 41 and 42 quantal values greater than 15 g, therefore, we obtain from table 41 values of 9.3 g, 3.2 g (probably representing 3 x 3.2 g = 9.6 g or 4 x 3.2 g = 12.8 g), and 12.3 g for the intact domed weights, and 3.2 g, 12.3 g, and 9.3 g for all domed weights; and, from table 42 values of 9.3 g, 12.3 g, and 3.2 g for the intact domed weights, and 3.2 g, 12.3 g, and 9.3 g for all domed weights.

The quantal value of 3.3 g on table 49 clearly corresponds to the quantal value of 3.2 g on tables 41 and 42. Moreover, the quantum of 9.3 g of the former tables is not seen in table 49 due to the removal from the domed-weight population all truncated spheres, which as a group conformed to a unit mass of 9.3 g. The quantum of 12.3 g of tables 41 and 42 have remained unchanged in table 49. The possible presence of this value in quantal analyses involving weights based on a unit mass of ca. 9.3 g has already been explained above, and, as such, will not be considered as a potential unit mass for the non-truncated domed weights.

It seems, then, the quantum of 3.3 g, probably corresponding to 9.9 g (3 x 3.3 g), is possibly the most likely candidate for the unit mass represented by these 20 weight pieces. One primary reason for separating these weights from the truncated spheres in the first place, however, was to seek for potential unit masses other than one of 9.3 g. The reason being that when evaluated on a unit mass of 9.3 g, these weights yield units of 4, 6, and 8, which are unlikely multiples for a decimally factored
system. Further examination of table 49 reveals 8.6 g as the next most likely unit mass for the intact weight pieces, with 2.7 g (possibly 3 \times 2.7 g = 8.1 g) following close behind; and, 2.6 g (possibly 3 \times 2.6 g = 7.8 g) for the search involving all non-truncated weight pieces. It seems, then, that in the assemblage of non-truncated spheres from Cape Gelidonya, there are possibly two unit masses represented: one in the vicinity of 8.6 g, and the other corresponding to a value between 7.8 g and 8.1 g. Needless to say, this result is meaningful only if two sets represented in the assemblage in question, that they are quantally configured, and both sets are represented by roughly the same number of elements. If that is indeed the case, how may we best separate the elements of each system? Again, separating the weight pieces according to morphological considerations seems sensible. In this instance, however, the weight pieces are mostly crudely shaped, which makes their attributions to either set extremely difficult.

Of the non-truncated sphendonoids, the following are of interest: W 11n (W 11), W 12n (W 12), W 16n (W 15), W 22n (W 20), W 29n (W 26), W 30n (W 27), W 31n (W 28), W 34n (W 31), W 41n (W 41), and W 50n (W 47). They have been grouped together not only from morphological grounds, but also because they are all significantly under or overweight, or are at the heavier end of the acceptable mass limit for a system based on a unit mass of ca. 9.3 g. Because of their shapes, which in many pieces are roughly truncated cones, this type will be referred to by that name. Table 50 gives the mass of each piece, its possible unit attribution, and the resultant unit mass based on a standard of ca. 9.3 g.

It will be observed from the tabulated values above that the unit mass of about half of the weight pieces is less than 9 g, which makes it almost certain that they cannot be elements of a set based on a unit mass of 9.3 g. One weight piece (W 41n [W 41]) is at the low end of the mass range that brackets the 9.3 g norm, while still others (W 16n [W 15], W 34n [W 31], W 50n [W 47]) are at the high end, making their attributions suspect. As such a wide variation in mass should not be considered
acceptable, how then may these weights be interpreted? It is almost certain that these seemingly under- or overweight pieces are instead elements of a set whose standard unit mass conforms to a value other than 9.3 g. Moreover, most are roughly shaped as truncated cones, a feature consistent with elements belonging to a different set. Submission of these weights to a quantal search yields the results in table 51.

Table 50. Attributions and resultant unit masses of truncated cones from Cape Gelidonya based on a standard unit mass of 9.3 g.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Mass</th>
<th>Probable Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 11n (W 11)</td>
<td>25.79 g</td>
<td>3</td>
<td>8.60 g</td>
</tr>
<tr>
<td>W 12n (W 12)</td>
<td>26.05 g</td>
<td>3</td>
<td>8.68 g</td>
</tr>
<tr>
<td>W 16n (W 15)</td>
<td>29.42 g</td>
<td>3 or 3-1/2</td>
<td>9.81 g or 8.41 g</td>
</tr>
<tr>
<td>W 22n (W 20)</td>
<td>43.69 g</td>
<td>5</td>
<td>8.74 g</td>
</tr>
<tr>
<td>W 29n (W 26)</td>
<td>51.35 g</td>
<td>6</td>
<td>8.56 g</td>
</tr>
<tr>
<td>W 30n (W 27)</td>
<td>53.61 g</td>
<td>6</td>
<td>8.94 g</td>
</tr>
<tr>
<td>W 31n (W 28)</td>
<td>53.90 g</td>
<td>6</td>
<td>8.98 g</td>
</tr>
<tr>
<td>W 34n (W 31)</td>
<td>58.79 g</td>
<td>6 or 7</td>
<td>9.8 g or 8.40 g</td>
</tr>
<tr>
<td>W 41n (W 41)</td>
<td>73.22 g</td>
<td>8 or 9</td>
<td>9.15 g or 8.14 g</td>
</tr>
<tr>
<td>W 50n (W 47)</td>
<td>146.23 g</td>
<td>15 or 18</td>
<td>9.75 g or 8.12 g</td>
</tr>
</tbody>
</table>

The most likely quantum corresponds to a value of 4.9 g (possibly 1/2 of 9.8 g), followed by 14.4 g, which possibly represents double of 7.2 g. The third peak corresponds to a quantum of 6.6 g (possibly 1/2 of 13.2 g), the fourth to 13.4 g, and the fifth to 2.7 g (possibly 1/3 of 8.1 g, 1/4 of 10.8 g, or 13.5 g). It seems, therefore,
that the first five maxima obtained through Kendall's statistic correspond to the
distinct quanta of 9.8 g, 14.4 g, 13.2 g/13.4 g, and 8.1 g as the most likely common
denominators, while the sixth peak corresponds to a quantum of 4.3 g, which possibly
represents 1/2 of 8.6 g or approximates the same value as the fifth quantum. Because
the error term \( \Phi (\tau) \) varies by only 0.097 from the second maximum to the sixth, all
four possible standard units should be considered carefully as potential candidates.
The ten weights, with their approximate denominational attributions based on standard

Table 51. Results of quantal search among the truncated cone weights from Cape
Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Probable Unit Attribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.9 g</td>
<td>( \Phi (\tau) = +2.148 )</td>
<td>1/2 of 9.8 g</td>
</tr>
<tr>
<td>2</td>
<td>14.4 g</td>
<td>( \Phi (\tau) = +1.665 )</td>
<td>1 or 2 of 7.2 g</td>
</tr>
<tr>
<td>3</td>
<td>6.6 g</td>
<td>( \Phi (\tau) = +1.662 )</td>
<td>1/2 of 13.2 g</td>
</tr>
<tr>
<td>4</td>
<td>13.4 g</td>
<td>( \Phi (\tau) = +1.655 )</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>2.7 g</td>
<td>( \Phi (\tau) = +1.644 )</td>
<td>1/3 of 8.1 g, 1/4 of 10.8 g, or 1/5 of 13.5 g</td>
</tr>
<tr>
<td>6</td>
<td>9.1 g</td>
<td>( \Phi (\tau) = +1.570 )</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>4.3 g</td>
<td>( \Phi (\tau) = +1.568 )</td>
<td>1/2 of 8.6 g or 1/3 of 12.9 g</td>
</tr>
<tr>
<td>8</td>
<td>8.6 g</td>
<td>( \Phi (\tau) = +1.554 )</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>7.3 g</td>
<td>( \Phi (\tau) = +1.196 )</td>
<td>1 or 1/2 of 14.6 g</td>
</tr>
<tr>
<td>10</td>
<td>3.2 g</td>
<td>( \Phi (\tau) = +1.156 )</td>
<td>1/3 of 9.6 g or 1/4 of 12.8 g</td>
</tr>
</tbody>
</table>

unit masses of 9.8 g, 14.4 g, 13.2 g, and 8.1 g appear in table 52.
If these 10 weights indeed make up a quantally factored set, then one based on a unit mass of 9.8 g is the least likely because such a system, essentially that of the Egyptian qedet is decimal in its mathematical structuring, and multiples of 2.5, 5.5, 6, and 7.5, among others, are not only impractical, but normally not found in decimally factored sets. A standard unit mass of 13.2 g appears to be somewhat better suited for the set, but it too includes unlikely multiples of 4.5, 5.5, and 11. A set based on a unit mass of 8.1 g also appears unlikely as it includes impractical multiples of 6.5 and 18. Moreover, its elements would appear to have been crafted poorly with regard to approximating their intended masses. It seems, then, that the most likely standard unit

Table 52. Possible unit attributions of Cape Gelidonya weights W 11n (W 11), W 12n (W 12), W 16n (W 15), W 22n (W 20), W 29n (W 26), W 31n (W 28), W 34n (W 31), W 41n (W 41), and W 50n (W 47), based on standard unit masses of 7.3 g, 9.1 g, and 8.6 g.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Mass</th>
<th>Standard Unit Mass of 9.8 g</th>
<th>Standard Unit Mass of 7.2 g (1/2 of 14.4 g)</th>
<th>Standard Unit Mass of 13.2 g (2 x 6.6 g)</th>
<th>Standard Unit Mass of 8.1 g (3 x 2.7 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 11n (W 11)</td>
<td>25.79 g</td>
<td>2.5</td>
<td>3.5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>W 12n (W 12)</td>
<td>26.05 g</td>
<td>2.5</td>
<td>3.5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>W 16n (W 15)</td>
<td>29.42 g</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>W 22n (W 20)</td>
<td>43.69 g</td>
<td>4.5</td>
<td>6</td>
<td>3</td>
<td>5 (?)</td>
</tr>
<tr>
<td>W 29n (W 26)</td>
<td>51.35 g</td>
<td>4.5</td>
<td>7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>W 30n (W 27)</td>
<td>53.61 g</td>
<td>5.5</td>
<td>7</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>W 31n (W 28)</td>
<td>53.90 g</td>
<td>5.5</td>
<td>7</td>
<td>4</td>
<td>6.5</td>
</tr>
<tr>
<td>W 34n (W 31)</td>
<td>58.79 g</td>
<td>6</td>
<td>8</td>
<td>4.5</td>
<td>7</td>
</tr>
<tr>
<td>W 41n (W 41)</td>
<td>73.22 g</td>
<td>7.5</td>
<td>10</td>
<td>5.5</td>
<td>9</td>
</tr>
<tr>
<td>W 50n (W 47)</td>
<td>146.23 g</td>
<td>15</td>
<td>20</td>
<td>11</td>
<td>18</td>
</tr>
</tbody>
</table>
of mass represented by these 10 weights is one that approximates 7.2 g, a value revealed by our quantal analysis to yield the second least error (table 51). A unit mass of 7.3 g for some of the Gelidonya weights was detected by Bass (1967) in multiples of 4 (W 15n [W 14]), 5 (W 19n [W 18]), 6 (W 22n [W 20]), 8? (W 34n [W 31]), 9 (W 36n [W 34]), 15 (W 49n [W 46]), 20 (W 50n [W 47]), 28 (W 55n [W 52]), 32 (W 59n [W 53]), and 64 (W 63n [W 58]). Of these, W 15n (W 14), W 36n (W 34), W 55n (W 52), and W 63n (W 58) are sphendonoids and, as such, have been treated above, while W 49n (W 46) is a piece of copper whose identity as a weight piece is rejected in this study.

As Bass’s proposed set of weights of this standard comprises pieces of different shapes (i.e., sphendonoid and domed types), however, the set as a whole fails to comply with our criterion of acceptable morphological homogeneity. It will be recalled that this criterion requires that distinct designs or shapes of weight pieces were purposeful and intended specifically to facilitate their recognition and facile separation from those of other standards or those reserved for different purposes. Removal from Bass’s set all the sphendonoids and W 7n (W 64), which we believe to be a piece of copper, leaves the following multiples: 5 (W 19n [W 18]), 6 (W 22n [W 20]), 8 (W 34n [W 31]), 20 (W 50n [W 47]), and 32 (W 59n [W 53]). All of these pieces except W 19n (W 18) and W 59n (W 53) are among the elements of the set proposed here. Weight piece W 59n (W 53) was incorrectly published as weighing 233.00 g, hence its 32-unit attribution to the 7.32-g standard by Bass. We have noted, however, that its mass is in fact 282.01 g, which makes it a good 30-unit piece of 9.3 g. Furthermore, because its shape conforms well to the typical truncated sphere category, weight W 59n (W 53) is most likely a member of that set.

The candidates for a Gelidonya set based on a standard unit mass of 7.2 g, therefore, represent the following multiples: 3.5 (W 11n [W 11], W 12n [W 12]), 4 (W 16n [W 15]), 6 (W 22n [W 20]), 7 (W 29n [W 26], W 30n [W 27], W 31n [W 28]), 8 (W 34n [W 31]), 10 (W 41n [W 41]), and 20 (W 50n [W 47]). It must be admitted
that regardless of a set's standard unit of mass and its mathematical structuring, multiples of 3.5, 6, and 7 seem unusual and impractical. Indeed, it is almost certain that some of these weights are elements from other sets based on different standards, but there is no doubt that they do not represent a system based on a unit mass of ca. 9.3 g, as they are definitely either too heavy or too light. A standard unit mass in the vicinity of 7.2 g, however, does seem to fit them relatively well. We therefore submit that while some of these ten Gelidonya weight pieces appear to represent unusual multiples, they are amply consistent with respect to both mass and morphological considerations, and thus satisfy the requirements for a set based on a specific standard unit mass. Until we come up with a better interpretation, then, we shall attribute them, albeit tentatively, to a set based on a unit mass of ca. 7.2 g. It appears, therefore, that in the Cape Gelidonya weight assemblage, we have isolated thus far two basic norms, one based on a unit mass of ca. 9.3 g, the other on one of 7.2 g. The Near Eastern standard that is closest to 7.2 g is the peyem, which, although incompletely understood, appears to occur in multiples of 4 and 10. It may be of interest to point out as well that doubling multiples of 3.5, 4, and 5 yield 7, 8, and 10 units, all of which are represented in our proposed set. If our attribution of these weights to the peyem is correct, then we may add that multiple units also appear to be obtained by doubling. As such, the set is able to produce all integer multiples from 4 to 20 and can weigh up to a maximum of at least 50 units, or approximately 365 g when all pieces in the set are used simultaneously.

Although the unit and 2-unit denominations are missing, if all the weight pieces lumped under the truncated cones are indeed elements of this type, then they appear to represent more than a single set, as there are three 7-unit pieces and two 3.5-unit pieces in the assemblage. Such duplication of these units is not needed in an efficiently assembled set, as most remaining integer units can be easily generated by the combinative manipulation of already existing weight pieces. It is clear, however, that the necessary number of duplicate denominations among the truncated cones are
lacking for us to suggest a second viable set. Consequently, it serves no purpose to further divide this type into additional sets. Perhaps future investigations at Cape Gelidonya will reveal additional weigh specimens to make this division possible.

The third distinct shape among the Gelidonya domed group appears in a series of weights with somewhat rounded tops, sides, and, in most cases, bases, often with lentoid sections or, in a few cases, those that may be better described as irregular disks. They are: W 10n (W 9), W 18n (W 17), W19n (W 18), W 20n (W16), W32n (W29), W 42n (W 39), W 43 n (W40), and W 48 n (W45). As with the truncated-cone set, the elements that may be attributed to this category are not as uniform in shape nor as carefully crafted as those in the set of truncated spheres. But despite the variety of shapes, these lentoid weights stand apart from the Gelidonya truncated spheres and truncated cones and all the Uluburun weights. Moreover, as with the truncated cones, most of these pieces appear to be misfits, unusual denominations, or mostly underweight compared to the truncated spheres, which have been shown to be based on a decimal progression of ca. 9.3 g. Weight pieces that have been incorporated into this lentoid type are listed in table 53 with their masses, proposed denominations, and resultant unit masses.

As the qedet standard, based on a decimal progression and a unit mass of ca. 9.3 g, normally does not incorporate 4-, 6-, or 8-unit denominations, all but two of these pieces, then, may be excluded from that system. The remaining two (W 10n [W 9] and W 48 n [W 45]) are significantly overweight if they are elements of that system. It appears, therefore, that the pieces listed in table 53, which are more or less morphologically compatible, belong to another standard. If so, what is it and how may we determine its standard unit mass?

As before, let these weights constitute the population of our lentoid type that will be submitted to two quantal searches using Kendall’s statistic, the first with only the five intact pieces (W 10n [W 9], W 18n [W 17], W 42n [W 39], W 43n [W 40], W
48n [W 45]) (table 54, left), followed by one with the masses of W 19n (W 18), W 20n (W 16), and W 32n (W 29) incorporated (table 54, right). It seems that the

Table 53. Cape Gelidonya lentoid weights with their proposed unit attributions and resultant unit masses.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Mass</th>
<th>Unit Attribution</th>
<th>Resultant Unit Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 10n (W 9)</td>
<td>20.53 g</td>
<td>2</td>
<td>10.27 g</td>
</tr>
<tr>
<td>W 18n (W 17)</td>
<td>35.83 g</td>
<td>4</td>
<td>8.96 g</td>
</tr>
<tr>
<td>W 19n (W 18)</td>
<td>36.19 g (-)</td>
<td>4</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>36.77 g (cal.)</td>
<td></td>
<td>8.96 g</td>
</tr>
<tr>
<td>W 20n (W 16)</td>
<td>27.32 g (-)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>35.00 g (est.)</td>
<td>4</td>
<td>8.75 g (est.)</td>
</tr>
<tr>
<td></td>
<td>37.04 g (cal.)</td>
<td>4</td>
<td>9.26 g (cal.)</td>
</tr>
<tr>
<td>W 32n (W 29)</td>
<td>55.79 g (-)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>57.45 g (cal.)</td>
<td>6</td>
<td>9.58 g (cal.)</td>
</tr>
<tr>
<td>W 42n (W 39)</td>
<td>75.67 g</td>
<td>8</td>
<td>9.45 g</td>
</tr>
<tr>
<td>W 43n (W 40)</td>
<td>76.63 g</td>
<td>8</td>
<td>9.58 g</td>
</tr>
<tr>
<td>W 48n (W 45)</td>
<td>99.31 g</td>
<td>10</td>
<td>9.93 g</td>
</tr>
</tbody>
</table>

quanta of 10.9 g (or 11.0 g), 4.5 g, and 7.6 g are the most likely candidates for the standard unit mass, or fraction(s) thereof, represented among the intact pieces. It is probable that 4.5 g is 1/2 of a unit of 9.0 g and that 10.9 g for the intact lentoids corresponds to the quantum 11.0 g observed among all lentoid weights. In fact, the only difference in the quanta of the two populations is that the positions of the first two (10.9 g [or 11.0 g] and 4.5 g) have been reversed.
Table 54. Peak values corresponding to the most likely quanta among the intact lentoids (left) and for all lentoids (right) from Cape Gelidonya.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Quantum</th>
<th>Error Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.0 g</td>
<td>$\phi (\tau) = +2.228$</td>
<td>9.5 g</td>
<td>$\phi (\tau) = +2.978$</td>
</tr>
<tr>
<td>2</td>
<td>7.0 g</td>
<td>$\phi (\tau) = +2.116$</td>
<td>5.1 g</td>
<td>$\phi (\tau) = +2.091$</td>
</tr>
<tr>
<td>3</td>
<td>11.0 g</td>
<td>$\phi (\tau) = +2.093$</td>
<td>7.1 g</td>
<td>$\phi (\tau) = +1.854$</td>
</tr>
<tr>
<td>4</td>
<td>3.3 g</td>
<td>$\phi (\tau) = +1.721$</td>
<td>12.4 g</td>
<td>$\phi (\tau) = +1.826$</td>
</tr>
<tr>
<td>5</td>
<td>12.5 g</td>
<td>$\phi (\tau) = +1.650$</td>
<td>4.1 g</td>
<td>$\phi (\tau) = +1.768$</td>
</tr>
<tr>
<td>6</td>
<td>5.1 g</td>
<td>$\phi (\tau) = +1.580$</td>
<td>2.6 g</td>
<td>$\phi (\tau) = +1.593$</td>
</tr>
<tr>
<td>7</td>
<td>4.5 g</td>
<td>$\phi (\tau) = +1.479$</td>
<td>3.6 g</td>
<td>$\phi (\tau) = +1.556$</td>
</tr>
<tr>
<td>8</td>
<td>7.6 g</td>
<td>$\phi (\tau) = +1.404$</td>
<td>4.5 g</td>
<td>$\phi (\tau) = +1.461$</td>
</tr>
<tr>
<td>9</td>
<td>5.9 g</td>
<td>$\phi (\tau) = +1.172$</td>
<td>3.3 g</td>
<td>$\phi (\tau) = +1.392$</td>
</tr>
<tr>
<td>10</td>
<td>9.6 g</td>
<td>$\phi (\tau) = +1.078$</td>
<td>2.3 g</td>
<td>$\phi (\tau) = +1.235$</td>
</tr>
</tbody>
</table>

According to the search results, therefore, unit masses in the vicinity of 8 g (2 x 4 g) or 12 g (3 x 4 g) for the intact pieces, and of about 9.5 g for the entire population are the most likely common denominators. The second-best quanta for each population are 7.0 g or 14 g (2 x 7 g), and 10.2 g (2 x 5.1 g), respectively, while the third-best are 11 g and 7.1 g or 14.2 g (2 x 7.1 g). As all of these values are strong candidates for the lentoid type’s standard unit mass, and as they also represent known Near Eastern standards in use in the Late Bronze Age, they will all be considered in the evaluation of the system’s norm. Table 55 lists the denomination of each lentoid weight piece based on the unit masses suggested by the first three maxima given by Kendall’s statistic.
Table 55. Unit attributions of Cape Gelidonya lentoid weights with respect to the three possible standard unit masses suggested by Kendall’s statistic.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Mass (grams)</th>
<th>units of: 7 or 7.1 g (grams)</th>
<th>units of: 8 g (grams)</th>
<th>units of: 9.5 g (grams)</th>
<th>units of: 10.2 g (grams)</th>
<th>units of: 11 g (grams)</th>
<th>units of: 12 g (grams)</th>
<th>units of: 14g (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 10n (W 9)</td>
<td>20.5</td>
<td>3 (6.8)</td>
<td>2.5 (8.2) or 3 (6.8)</td>
<td>2 (10.3)</td>
<td>2 (10.3)</td>
<td>1.5 (13.7) or 2 (10.3)</td>
<td>1.5 (13.7)</td>
<td></td>
</tr>
<tr>
<td>W 18n (W 17)</td>
<td>35.8</td>
<td>5 (7.1)</td>
<td>5 (7.1)</td>
<td>4 (9.0)</td>
<td>3.5 (10.3) or 4 (9.0)</td>
<td>3 (11.9)</td>
<td>3 (11.9)</td>
<td>2.5 (14.3)</td>
</tr>
<tr>
<td>W 19n (W 18)</td>
<td>36.2 (-)</td>
<td>36.8 (cal.)</td>
<td>5 (7.4)</td>
<td>4 (9.2)</td>
<td>3.5 (10.5) or 4 (9.2)</td>
<td>3 (12.3)</td>
<td>3 (12.3)</td>
<td>2.5 (14.7)</td>
</tr>
<tr>
<td>W 20n (W 16)</td>
<td>27.3 (-)</td>
<td>37.0 (cal.)</td>
<td>5 (7.4)</td>
<td>4 (9.3)</td>
<td>3.5 (10.6) or 4 (9.3)</td>
<td>3 (12.4)</td>
<td>3 (12.4)</td>
<td>2.5 (14.8)</td>
</tr>
<tr>
<td>W 32n (W 29)</td>
<td>55.8 (-)</td>
<td>57.5 (cal.)</td>
<td>8 (7.2)</td>
<td>7 (8.2)</td>
<td>6 (9.6)</td>
<td>6 (9.6)</td>
<td>5 (11.5)</td>
<td>5 (11.5)</td>
</tr>
<tr>
<td>W 42n (W 39)</td>
<td>75.7</td>
<td>10 (7.6) or 11 (6.9)</td>
<td>10 (7.6)</td>
<td>8 (9.5)</td>
<td>7 (10.8) or 8 (9.5)</td>
<td>7 (10.8)</td>
<td>6 (12.6)</td>
<td>5 (15.1)</td>
</tr>
<tr>
<td>W 43n (W 40)</td>
<td>76.6</td>
<td>10 (7.7) or 11 (7.0)</td>
<td>10 (7.7)</td>
<td>8 (9.6)</td>
<td>8 (9.6)</td>
<td>7 (11.0)</td>
<td>6 (12.8)</td>
<td>5 (15.3)</td>
</tr>
<tr>
<td>W 48n (W 45)</td>
<td>99.3</td>
<td>14 (7.1)</td>
<td>12 (8.3)</td>
<td>10 (9.9)</td>
<td>10 (9.9)</td>
<td>9 (11.0)</td>
<td>8 (12.4)</td>
<td>7 (14.2)</td>
</tr>
</tbody>
</table>
A standard having a unit mass of about 9.5 g with essentially binary
denominations seems to fit the lentoid type fairly well. Among the reasons for
submitting the lentoid weights to a quantal search in the first place, however, was that
its multiples of 4-, 6-, and 8- do not represent units normally observed in the
decimally configured *qedet* system. Further, two of the weight pieces (W 10n [W 9]
and W 48n [W 45]) conforming to these apparently binary denominations are
overweight, while one other (W 18n [W 17]) is underweight, and fall outside the
acceptable range of the mass values attributed to the *qedet* standard. Consequently,
we can eliminate the quantal value of 9.5 g as a possible unit mass for the lentoid set.
A standard based on a unit mass of 11.0 g for the lentoids produces multiples of 2, 3,
5, 7 and 9; one of 10.2 g gives 2, 3.5, 6, 7, 8, and 10; while one of 14.0 g yields 1.5,
2.5, 4, 5, and 7, all of which include several denominations one would normally not
expect to find in weight sets. Standards based on a unit mass of 7 g - 7.1 g, 8 g, and
12 g, on the other hand, produce slightly more reasonable multiples of 3, 5, 8, 10, 14;
2.5, 5, 7, 10, 12; and 1.5, 3, 5, 6, 8, respectively. While Kendall's statistic has shown
the quantum of 4 g to give the least amount of error as the set's common denominator,
hence our proposed sets based on unit masses of 8 g (2 x 4 g) and 12 g (3 x 4 g), the
error terms for 7 g - 7.1 g and 5.1 g (possibly 1/2 of 10.2 g), follow closely behind. Of
the last two standards, one based on a unit mass of 7 g - 7.1 g does not yield any non-
integer units, and incorporates the least number of unlikely denominations. It seems,
then, that the lentoid weight pieces appear to conform somewhat marginally better to a
standard based on a unit mass in the vicinity of 7 g to 7.1 g. There is no known
standard in the Near East with such a light unit mass, as this value is well below the
acceptable lower limit for the *peyem*. If this quantum does indeed represent the unit
mass for the lentoids, then in all likelihood the truncated cones, which seem to
conform to a slightly heavier unit mass, must also incorporate the same norm. While
both standard unit masses are rather light, the *peyem* still remains the only norm that
these irregular weight pieces may be attributed to. It is almost certain that both the
truncated cones and the lentoid types incorporate several sets, which, in all likelihood, represent more than one standard. Moreover, because of their relatively non-distinct morphological characters, certain specimens were probably incorrectly attributed to their respective types. Clearly, much more work needs to be done on these two elusive types before we can better define their underlying structure.

It seems, then, the sphendonoids comprise three separate sets of weights, all of which are based on a unit mass of ca. 9.4 g, a norm known to have originated in Egypt and to have been widely used along the Syro-Palestinian coast. Unlike the typical Egyptian qedet or its Syrian counterpart, however, those of Gelidonya are not completely decimal in their mathematical structuring, that is, the fundamental unit of the decimal system, the number 10, is non-existent among the Gelidonya sphendonoids, although multiples of 1, 2, 3, 5, 20, 30, and 50 are present. The 10-unit weights appear to have been replaced by 7-unit pieces, virtually unknown denominations in the Syrian/Ugaritic shekel norm. We have attempted to show how the 7-unit pieces in the Gelidonya sphendonoid group could correspond to the Aegean unit of ca. 65 g. Therefore, it has been proposed here that by this simple change in otherwise decimally structured sets, a dual weighing property, or bivalence, was imparted to them to facilitate their use as weighing tools in both the Syrian/Ugaritic shekel and Aegean systems. The heaviest of the Gelidonya sphendonoids (W 64n [W 60]) probably is the only element among the assemblage to represent the Mesopotamian shekel of ca. 8.3 g.

The domed weights include at least three distinct types. Those in the shape of truncated spheres are typical decimally factored qedets of ca. 9.4 g. There may, in fact, have been two such sets originally, but only one is nearly complete while the other includes only some of the larger denominations. Another set, shaped as crudely fashioned truncated cones, may represent a standard based on a unit mass of ca. 7.3 g, the peyem. The third set among the domed weights comprises the least uniformly crafted pieces, which mostly appear to be primarily lentoid in sectional shape. The
unit mass on which the set is based is not very clear, but of the possibilities, one of ca. 7.1 g seems the most likely. If this is in fact the case, then the lentoid weights also appear to represent the peyem, albeit an unusually light variation of it.

Discussion

Statistical considerations require the masses of balance weights to conform to the same error distribution as any other population of objects subjected to mensuration. As such, the norm, or standard unit mass, represented by each weight will fall on either side of the mean value for the unit mass. The tightness and symmetry (or scatter) of this distribution of the unit masses will be dictated by the care with which the weights were manufactured, the precision of the reference balance weights available to the craftsmen, and by the economic conditions in a particular place at a specific time, which may have promoted a slight bias toward undervalued weights to benefit the merchant, or even the occurrence of outright fraudulent balance weights. It would be unrealistic, and most unfruitful, therefore, to try to derive from a single balance weight specimen an inherent unit mass representing the standard to which the weight was fashioned. This consideration applies even to balance weights that are inscribed and display superior craftsmanship in their manufacture. While it may be true that in some instances, inscribed weights, especially those bearing royal names, can be taken as more precise representatives of their standards than uninscribed and poorly manufactured pieces, we still can never be certain as to the precision of the reference weights used to verify the masses of the inscribed weights. In short, unless we have in our possession a seemingly unequivocal example of a sanctioned weight, the mass of an individual weight should not be taken to represent a precise single unit, fraction, or multiple of a standard, but rather as a reasonable attempt to create a denomination within a margin of error deemed acceptable to the purpose for which that specific set of balance weights was designed and manufactured.
With this in mind, a statistical (Kendall's) approach devoid of bias toward any mass standard has revealed convincingly that for the great majority of balance weights in the Cape Gelidonya assemblage, a standard whose unit mass is ca. 9.3 g seems to fit the group with the least error. Division of the assemblage into two major groups based on recognizable shapes, followed by the reapplication of Kendall's statistic, does not change to any great extent the overall results of the initial analysis, though subsequent analyses of the different sets within the two groups seem to isolate a slightly different standard unit mass in each set. At this point in our investigation it is difficult, if not impossible, to state conclusively whether the proposed sets of balance weights identified among the Cape Gelidonya sphendonoids, which correspond to unit masses of ca. 9.3 g and 9.8 g, represent different standards, or merely the same standard crafted to different levels of acceptability, or nearly the same standard, as revealed by their respective mean resultant weighted averages. Another standard, the Mesopotamian shekel, appears to be represented by a single balance weight (W 64n [W 60]) that may have been a remnant from a previous set, a solitary functional weight of 1 mina, or something simply kept as a curiosity piece.

In his uniquely intuitive approach to determining the mass standards represented among the Gelidonya weights, Bass follows an exemplary method of his own design that does not take their shapes and the quality of craftsmanship into account, a method that is devoid of prejudice against or bias toward any known ancient mass standards or other external factors. As such, it will be useful to briefly describe his approach.

After studying the weights in light of known ancient weight standards and finding many values attributable to some of the common standards or their dozens of variations, Bass abandoned this course in favor of one he created himself. He devised a grid system whereby each weight's mass was placed along one axis of the grid and integers (from 2 to 15 for the lighter weights, but up to 60 for the heavier pieces) along the other. Each mass was divided by each integer, calculated to two significant
digits, and the quotient was entered at their point of intersection on the grid. Bass noted each quotient that repeated exactly, along with its frequency, and then repeated the count to include values that deviated from those of the first group by 1/10 of a gram. Instances of repetition, with and without their deviations, were taken to be the standards represented by the respective weight pieces. Herein lies one of the difficulties in Bass's method. This innovative intuitive approach is commendable, but its application for determining standard units is much too rigid in this instance. In particular that the mass of 9.32 g occurred four times and 9.33 g three times in the grid was taken to document the precision by which ancient balance weights were manufactured. Such precision was then taken as testimony to the sensitivity of ancient balances, with the conclusion that they appeared to be much more precise than previously documented (Bass 1967: 142), for example by Skinner (1954).

In fact, reweighing all of the Gelidonya weights after extensive cleaning and thorough desalination has shown differences between the published and newly measured masses of 57 of the 60 published pieces (two could not be located for restudy and one has been rendered underweight through loss of its associated fragments). Over 49% vary from their published masses by more than 3/10 of a gram. The magnitudes of these variations and their respective occurrences are summarized in table 56.

It is clearly evident that complete cleaning of the Gelidonya balance weights has yielded mass variations of over 1/10 of a gram in more than 75% of the assemblage, and of 1 gram or more in nearly 19% of the pieces. Under these circumstances, therefore, to establish standard mass units within such a narrow tolerance of only 1/10 of a gram is not meaningful.

In this connection we may also point out that it appears likely the masses were measured to only ± 1/10 of a gram (to one significant digit), even though they are published with two significant digits (to 1/100 of a gram). This is strongly suggested by the fact that for all the weight pieces, the digit in the hundredths column is a 0, a
Table 56. Differences between published and recently measured masses of the Cape Gelidonya weights.

| Absolute value of change (|x|) between published and recently measured masses | Number of weights/Total number of weights | Percentage (%) |
|-------------------------------------------------|------------------------------------------|----------------|
| |x| < 0.1 g                                         | 43/57                                     | 75.44          |
| 0.1 g < |x| ≤ 0.2 g                                       | 35/57                                     | 61.40          |
| 0.2 g < |x| ≤ 0.3 g                                       | 28/57                                     | 49.12          |
| 0.3 g < |x| ≤ 0.4 g                                       | 22/57                                     | 38.60          |
| 0.4 g < |x| ≤ 0.5 g                                       | 17/57                                     | 29.82          |
| 0.5 g < |x| ≤ 1.0 g                                       | 11/57                                     | 19.30          |

consistency that would seem to be a virtual impossibility. This innocent or inadvertent act in fact nullifies Bass’s claim that these balance weights were crafted to mass accuracies of two significant figures. To illustrate, consider weight W 29n (W 32) in Bass’s table 1 (Bass 1967: 138), in which its mass is given as 63.90 g. This value, in all probability, was determined as simply 63.9 g, with the zero having been appended only after weighing was completed. But such use of a zero should in fact indicate that the piece was determined to weigh precisely 63.90 g and not, say, 63.91 g. If W 35n (W 32) was indeed originally weighed as 63.9 g and not 63.90 g, its actual mass to two significant digits could have been anything between 63.90 g and 63.94 g (assuming the last digit was rounded off to the next figure if 5 or greater). In absolute terms such a small difference is inconsequential, but it is sufficient to reveal the error in Bass’s claim that 26 of the 52 Gelidonya weights are accurate to ± 1/100 of a gram or less per unit mass (Bass 1967: 142). Consequently, the argument for remarkably precise ancient balances is not supported by this evidence. Assuming then that the
calculated unit masses published by Bass are not the result of fortuitous coincidence, they suggest a sensitivity for balances on the order of tenths of a gram at most.

Another problematic aspect of Bass's method involves the minimum number of weights that can constitute a useful set. For a group or a set of weights to be viable and efficient over a broad mass range it must comprise a minimum number of elements that, when used singly or in combination, can be manipulated to generate all necessary mass multiples. For a basic set this requires the presence of at least one each of unit fractions and common multiples, and perhaps even several pieces of some of the larger denominations to facilitate weighing higher mass values without having to repeatedly use many of the smaller weight pieces. If we are to accept all of the conclusions regarding the eight different standards Bass derived for the Cape Gelidonya weights, some of which appear to be represented by only a few pieces, then we must acknowledge exceptions to all of the above considerations and maintain extremely flexible criteria with respect to viability, efficiency, convenience of mental tallying, and simple common sense.

In his examination of the Cape Gelidonya weight assemblage, Parise (1971) is unquestioning in his acceptance of Bass's argument that balances were extremely sensitive and that the weights were manufactured with great exactness. But he does object categorically to grouping the weights based on unit masses varying by ± 1/10 of a gram and, correctly in my opinion, argues that their unit masses should, as do most data, subscribe to a statistical, or bell-shaped, distribution. By evaluating the Gelidonya balance weights in terms of broader error limits and dismissing unlikely or impractical multiples, Parise (1971: 170) proposes in place of the eight mass standards submitted by Bass only a single standard that incorporates norm values between ca. 59.0 g and 69.8 g (normalized to about 65 g), which are observed for most of the Aegean region but also incorporate many or all of the Near Eastern mass standards. This most intriguing interpretation may explain in the Gelidonya sphendonoid group the preponderance of weights in the 63-69 g range, which otherwise represent
impractical or unlikely 7-unit multiples of a standard unit mass in the range of 9.2 g - 9.8 g. Among the Gelidonya domed weights, on the other hand, there are no weight pieces in this range, although at least four between 53 g and 59 g correspond to equally impractical or unlikely 6-unit multiples of the same standard. Parise's proposal for the existence of a single standard based on the Aegean unit that also appears to incorporate many or all of the Near Eastern weight standards, therefore, is not fully satisfying. Moreover, quantal searches within the Gelidonya weight assemblage demonstrate that the most likely primary unit mass is in the 9.2 g - 9.8 g range for both the sphendonoid- and dome-shaped weights. It should be noted that other less likely values revealed by the same quantal searches could be regarded as fractions of a unit in the range of 60 g - 69 g, but their corresponding error terms fall short of what one would expect for any set of balance weights. The nature of results one could expect from an Aegean weight assemblage is best illustrated by weights that have been convincingly demonstrated to belong to that standard. For such an assemblage we may consider the collection of weights from Ayia Irini on Keos. Petruso (1992: 22-26) cataloged 55 weights from the site, only 45 of which were well enough preserved to be included in a quantal search for the standard unit mass of the group. Subjecting these weights to Kendall's statistic and plotting the resulting quanta against the error terms (fig. 21) yields results that are quite different from those obtained for the Gelidonya weights. The top ten maxima for the assemblage are given in descending order in table 57.

Given that the peaks or maxima of 32.2 g, 30.2 g, and 33.2 g peripheral to the primary peak of 31.3 g essentially represent 1/2 of the same unit mass (interpreted thus by Petruso), and that the next three highest peaks corresponding to quantal values of 5.0 g, 3.9 g, and 20.2 g may be taken to represent respectively 1/12, 1/15, and 1/3 of the same unit mass, the standard unit mass in use at Ayia Irini is established as just over 60 g (Petruso 1992: 32-33). The use of a standard similar to that in evidence at
Ayia Irini has been demonstrated also for Crete, many of the Aegean islands, and parts of the Greek mainland (Petruso 1992).

Comparison of the quantal search results for the Ayia Irini weights with those for Gelidonya reveals widely divergent maxima values. The Ayia Irini assemblage yields as its most likely quantum a mass of 31.3 g (1/2 of 62.6 g), whereas for the Gelidonya weights the quantal value with the least error corresponds to a mass of about 9.7 g. We may state with some confidence, therefore, that even if an Aegean standard is somehow represented in the Gelidonya weight assemblage, its standard unit
Table 57. Peak values corresponding to the most likely quanta represented among the 45 well-preserved weights from Ayia Irini, Keos.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.3 g</td>
<td>( \phi (\tau) = + 3.195 )</td>
</tr>
<tr>
<td>2</td>
<td>5.0 g</td>
<td>( \phi (\tau) = + 2.991 )</td>
</tr>
<tr>
<td>3</td>
<td>32.2 g</td>
<td>( \phi (\tau) = + 2.910 )</td>
</tr>
<tr>
<td>4</td>
<td>30.2 g</td>
<td>( \phi (\tau) = + 2.828 )</td>
</tr>
<tr>
<td>5</td>
<td>3.9 g</td>
<td>( \phi (\tau) = + 2.805 )</td>
</tr>
<tr>
<td>6</td>
<td>33.2 g</td>
<td>( \phi (\tau) = + 2.533 )</td>
</tr>
<tr>
<td>7</td>
<td>20.2 g</td>
<td>( \phi (\tau) = + 2.201 )</td>
</tr>
<tr>
<td>8</td>
<td>14.9 g</td>
<td>( \phi (\tau) = + 2.031 )</td>
</tr>
<tr>
<td>9</td>
<td>19.7 g</td>
<td>( \phi (\tau) = + 1.913 )</td>
</tr>
<tr>
<td>10</td>
<td>15.6 g</td>
<td>( \phi (\tau) = + 1.848 )</td>
</tr>
</tbody>
</table>

mass is unrelated to the unit mass used at Ayia Irini. Therefore, we cannot conclude that a standard documented for much of the Aegean is also present, at least in the same mathematical structuring, in the Gelidonya weights.

In his study of Late Cypriot weight metrology, Petruso (1984: 293-304), like Parise, proposes for the Cape Gelidonya assemblage a single system, decimal in nature, but one whose standard unit mass is just under 9.5 g, as in the system apparently used on Cyprus during the Late Bronze Age, rather than one of ca. 65 g, as argued by Parise. Unlike Bass, who apparently pursued no correlation between the shapes of the Cape Gelidonya balance weights and the standards known to have been in use at the time, Petruso believes, as I do, that the shapes were indeed significant, though not
necessarily indicative of different standards (Petruso 1984: 295). Petruso divides the Cape Gelidonya weights into two basic morphological groups: the sphendonoid weights and the domed weights. The groups are based on a standard unit just under 9.5 g in mass, but the multiples in each group appear to be reflect different progressions. The domed weights occur in simple and useful decimal increments of 5, 10, 15, 20, 25, 30, and 50 units, whereas for the sphendonoids a more complex series of 1, 3, 5, 7, 12, 31, and 50 units is noted. The latter series suggests to Petruso (1992: 299, 302-303) that the Cape Gelidonya sphendonoids were generated according to what is known as the Fibonacci series, whereby each subsequent element is the sum of the two integers that immediately precede it. Based on these observations Petruso concludes that both groups represent the same system, but that the domed weights are decimal in structure and the sphendonoids are additive (Petruso 1984: 302).

Petruso's suggested reconstruction for the Cape Gelidonya sphendonoid weights is most provocative, as it attempts to explain the presence of the unusual multiples of 7, 12, and 31 in the group. His argument for the standard unit mass on which the system was based is convincing, and correct in my view, though incomplete. That the two major weight shapes, domed and sphendonoid, represent separately structured sets is also argued convincingly. But our re-examination and re-evaluation of the Cape Gelidonya weight assemblage reveals the structures of these sets to be not as coherently delineated as Petruso presents. While admitting that he cannot explain all the Gelidonya weights, Petruso seems to favor pieces, at least in the case of the domed weights, that fit his proposed models best. For example, when seeking to demonstrate the decimal basis of the domed weights, 7 (W 12n [W 12], W 18n [W 17], W 22n [W 20], W 29n [W 26], W 31n [W 28], W 48n [W 45], W 54n [W 51]) of the 16 weights cataloged by Bass as dome shaped are excluded from his selection (W 25n [W 23], W 46n [W 43], W 47n [W 44], W 50n [W 47], W 52n [W 49], W 53n [W 50], W 59n [W 53], W 57n [W 55], W 61n [W 57]). In fact, had all 16 weights been considered, one weight in particular, W 31n (W28) at 53.90 g, would have clouded the
neat and distinct decimal progression. This weight and two others appear to represent 6-unit pieces, which seems an unlikely multiple for a system factored on decimal progression. Much of Petruso's apparent bias, however, stems from the difficulty of determining from the Cape Gelidonya final report the actual shapes of the weight pieces and the materials from which many of them were fashioned.

For his elaborate mathematical model of the Cape Gelidonya sphendonoid weights, Petruso selected as his working set only the 13 pieces specifically published by Bass as sphendonoid in shape (W 2n [W 2], W 14n [W 13], W 23n [W 22], W 24n [W 21], W 35n [W 32], W 39n [W 33], W 36n [W 34], W 37n [W 35], W 38n [W 36], W 49n [W 46], W 60n [W 56], W 63n [W 58], and W 64n [W 60]). Petruso saw a Fibonacci series in these increments of 1, 3, 5, 7, 12, 31, and 50 units, based on a norm just under 9.5 g in mass. However, the true Fibonacci series runs as follows: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, and so on. Petruso attempted to explain this discrepancy as the result of an easily executed shift from 8 to 7 that permitted generation of a 50-unit, or 1-mina, weight piece instead of a not-so-useful 55-unit piece. Such a modified Fibonacci series is therefore 1, 1, 2, 3, 5, 7, 12, 19, 31, 50, etc. After the missing 1-, 2-, and 19-unit pieces are restored to the Gelidonya group, the revised Fibonacci series becomes a perfect match for the progression of units Petruso suggests. He offers as compelling evidence for the existence of a missing 19-unit piece the presence of 31- and 50-unit weight pieces, which are sums of 12 + 19 and 19 + 31, respectively. He also notes that 19 + 31 + 50 = 100, a value that corresponds to the basic unit of mass in the next order of magnitude.

Our re-examination of the Gelidonya weights reveals that of the 13 pieces described by Bass as sphendonoids, only 8 are of the typical sphendonoid shape (W 2n [W 2], W 14n [W 13], W 23n [W 22], W 35n [W 32], W 37n [W 35], W 39n [W 33], W 60n [W 56], W 64n [W 60]), while the remaining weights are what we have termed the cylindrical and loaf-shaped pieces within the general sphendonoid group. We caution again, however, that morphological evaluations based on similar or dissimilar
features are usually subjective and should not be used as the basis for making definitive judgements. Certainly there are many more Gelidonya pieces that could have been incorporated in the general sphendonoid group, but were excluded from Petruso’s study, simply on the basis of published identifications. Furthermore, included among the 13 weights evaluated by Petruso is an oblong piece published by Bass as a roughly sphendonoid weight (W 49n [W 46]), but which on closer examination appears to be a fragment of blister copper, and whose use as a weight is, in my opinion, rather doubtful. Even if this object were used on the ship as perhaps a make-do weight, because of its susceptibility to corrosion, its present mass of 108.15 g is significantly less than its original value. In either case, it could not have corresponded to a 12-unit weight piece, which is one of the crucial building blocks of Petruso’s additive series hypothesis. In fact, the original mass of this copper piece has now been estimated at ca. 141 g, a value that would correspond to 15 units of 9.4 g if it were indeed used as a weight. Another weight piece Petruso advances in support of his additive-system hypothesis is W 60n (W 56) of 31 units, published originally as weighing 284.5 g. After being cleaned this piece was reweighed at 283.59 g, and is just as comfortable as a 30-unit piece of 9.45 g as one of 31 units of 9.15 g, if not more so.

Although the additive model proposed by Petruso generally does not appear to have been altered significantly, and the recent discovery of W 7n (W 64), corresponding to a 2-unit piece even restores one of Petruso’s theorized missing weights, there are in fact profound changes. In the typical sphendonoid series we no longer have a 50-unit weight piece, for as noted earlier, W 64n (W 60) probably represents a 60-unit piece or mina of the Mesopotamian standard of 8.32 g, rather than a 50-unit piece of 9.99 g per unit. Nor are there any 12-unit weight pieces for any of the sets, and in addition to the 7-unit pieces there is now a 6-unit piece for one set. Finally, the 31-unit piece is a much better 30-unit piece. As intriguing as Petruso’s additive-series hypothesis may be, therefore, the evidence for its existence among the Cape Gelidonya sphendonoids is inconclusive at best.
As with the anomalous 7-unit denominations (and a single 6-unit piece) attested for the Gelidonya sphendonoids, in the domed group we are also confronted with unusual multiples, this time of 4, 6, and 8. Even a casual examination of the Gelidonya sphendonoid and domed weights (tables 28 and 40) reveals that they are based on a decimal system, though the multiple units of the two groups are different and probably based on separate progressions. Most significant is that while the 10-unit denomination is totally absent from the Gelidonya sphendonoids, it is, along with the 6-unit denomination, the most common domed multiple after the 5-unit pieces. The most common denomination among the sphendonoids, the 7-unit piece, is absent from the domed group.

In fact, our reconstruction of the major denominations of the Gelidonya sphendonoid and domed weights based on a standard unit mass of ca. 9.4 g, or a mina of ca. 465-470 g, appears to be verified by impartial quantal analysis. This agrees with Petruso’s derived standard unit mass for the Gelidonya weights. The 7-unit multiples within the sphendonoids and the 4-, 6-, and 8-unit multiples among the domed weights are unusual and difficult to explain, especially in light of the much larger and more comprehensive assemblage of balance weights from the older Uluburun ship, where such multiples are non-existent. If the Gelidonya and Uluburun weight assemblages represent systems based on the same provisional standard unit mass of ca. 9.4 g, how, then, may we explain the apparent disparity of units in these diachronic weight deposits? Perhaps the solution lies in a system, at least in the case of the sphendonoids, that incorporates both Petruso’s and Parise’s proposals. That is, a decimally configured system based on a unit mass of ca. 9.4 g that is also designed to incorporate another standard based, for example, on a unit mass of ca. 65 g.

Starting with the assumption that the shapes of balance weights are significant indicators of different systems or sets (Petruso 1984: 302), let us first look only at the Cape Gelidonya sphendonoids. Comparing them with those from Uluburun quickly reveals three distinct peculiarities. First, none of the Gelidonya sphendonoids are
metal, nor is any provided with a lead plug for finely adjusting the mass. Second, the Gelidonya weights do not include any fractional units, whereas such are quite common among the Uluburun sphenodonoids. Third, the Gelidonya multiple-unit sphenodonoids include heavy pieces in the 50-unit (1-mina) range, while with one exception, those of the Uluburun wreck do not exceed multiples greater than 10. It appears, therefore, that the Uluburun sphenodonoids, while based on the same unit mass (ca. 9.4 g) as those of Gelidonya, are specifically designed to weigh much smaller quantities, presumably of valuable commodities. Fourth, and perhaps most significant is the absence of 10-unit multiples among the Gelidonya sphenodontoid assemblage, which contrasts sharply with the fact that at Uluburun there are nine such weights. Finally, the 7-unit is non-existent among the Uluburun weights, whereas, with 6 examples, it is the most common multiple unit for the Gelidonya sphenodonoids.

The uniqueness and importance of the 7-unit weights of ca. 65 g at Gelidonya was first noticed by Parise (1969: 168). He suggested with the utmost caution that such a unit allowed for the amalgamation of different weight standards based on binary (Aegean) and decimal (Syrian, Cypriot, and Egyptian) systems. He noted further that it was possible to see in the use of these pieces a deliberate attempt to organize into a *koine* the weight systems of the eastern Mediterranean, whereby each standard could be converted into any another. In his analysis of the Cape Gelidonya weights, Parise (1971: 163-64) regarded all weights between 63.90 g and 69.80 g (W 35n [W 32], W 36n [W 34], W 37n [W 35], W 38n [W 36], W 39n [W 33], W 40n [W 38], W 44n [W 37]) as representing approximately the same unit. These, with the exception of W 44n (W 37) (eliminated in our study because it is probably just a piece of copper), have been designated as 7-unit pieces in this study. Their current masses vary slightly from those published by Bass, but these marginal discrepancies matter little here. Parise also pointed out that six of the eight standards determined by Bass for the Gelidonya weights appear to fall within an interval of only 4.3 g (65.5 g - 69.8 g), with some only 0.2 g apart. He therefore advanced statistical considerations as to the difficulty, if not
the impossibility, of discriminating between elements of two different sets. That Parise is essentially correct in his objection has already been demonstrated in this study by the observed changes in mass of weight pieces subjected to thorough cleaning. Following Petrie's view that unjustified, irregular multiples make mental tallying difficult and are therefore unlikely, Parise dismisses the 7-unit multiple interpretation in favor of a larger standard mass unit that incorporates all seven specimens from Gelidonya (W 35n [W 32] - W 40n [W 38]) into a unique standard based on an Aegean system. In support of this interpretation he introduces as evidence weights from Knossos, Keos, and Thera (Parise 1971: 167-68). These are mostly lead weights, with only a few stone pieces among them, in the typical disk shapes found in much of the Aegean. Based on his work with the weights from Ayia Irini, on Keos, Petruso (1992) established for the Aegean a binary system of mass mensuration based on a unit mass of ca. 61 g. Yet because nearly all the weights from Ayia Irini are of lead and have been cleaned thoroughly, one cannot but wonder how much mass loss they have suffered and what effect, if any, this may have had on the value of the unit mass Petruso derived. Of interest, however, is an oblong stone object from Thera that weighs 66.5 g (Parise 1971: 167). As published, this object is described as a naturally polished pebble, but because it was found in association with balance weights, it too is assumed to have served that function (Marinatos 1969: 123, pl. 1198; 1969: 49-50, fig. 37, pl. 41.2). The shape of this pebble weight is conspicuously similar to those of some of the Gelidonya cylindrical weights and one may wonder if it was selected because of its similarity to Near Eastern sphenodontoid weight pieces. While it may appear futile to promote a naturally shaped and polished pebble as a possible example of a Near Eastern sphenodontoid-type weight from the Aegean that conforms to the Aegean standard unit mass, it is of further interest to note that the associated pebbles in the Ayia Irini group are spherical, also a non-Aegean shape. The choice of an oblong pebble in this instance, therefore, may have been more than mere coincidence.
Zaccagnini (1986: 420) interprets the ca. 65 g. weights as representing 8 units of the well-known shekel of ca. 7.9 g, as well as 10 units of a shekel of ca. 6.5 g. Like Parise, he believes that the "65 g" denomination represented an important link in a presumed relationship between the Mycenaean weight system and other Late Bronze Age Near Eastern weight systems. He argues for the antiquity of such weights by citing two from Early and Middle Bronze Age contexts at Ebla, of 64.2 g and 68.7 g. The latter weight exhibits six incised lines that have been interpreted as denoting 6 units of the Hittite shekel of 11.45 g. He also notes an example from Egypt weighing 67.26 g and marked "5 dbn," i.e., 5 units of 13.45 g, and an unmarked piece of 65.5 g from Ras Shamra/Ugarit. For Ras Shamra/Ugarit, Courtois (1990: 122) mentions seven specimens in the range of 66 g to 70 g that he takes as probably representing 6 shekels of the Hittite standard. After providing other examples of weights in the 1- unit and multiple-unit denominations that could correspond to a unit mass value in the range of ca. 6.5 g to 7.08 g, Zaccagnini proposes a new standard based on a unit mass of ca. 6.5-6.8 g, of which the Aegean unit would represent 10 units. He notes further that although the average unit mass value of the Near Eastern weights (including those from Egypt) based on this proposed standard unit mass is "heavier" than that of their Aegean counterparts, the overall variation in mass still appears to be within the 59.92-68.37 g range suggested by Parise (1971). Zaccagnini (1986: 422) sees in his shekel of 6.5-6.8 g a 5/6-fraction of the shekel of 7.9 g, which is, in turn, 5/6 of the shekel of 9.4 g. Accordingly, he describes the metrological relationship between these two norms as follows: the 6.5-6.8 g shekel represents the sexagesimal sub-division (i.e., by 3,600 shekels) of the "light" Ashdod talent of ca. 23.7 kg (of 3,000 shekels). That is, 3,600 shekels of 6.5-6.8 g (=23.4 kg to 24.48 kg) is approximately equal to 3,000 shekels of 7.9 g (= 23.7 kg). He thus ascribes to the 6.5-6.8 g shekel a function that parallels that of the shekel of 7.9 g, through which the Mesopotamian sexagesimal talent of 3,600 shekels is essentially equated with the "western" decimal talent of 3,000 shekels: 3,600 x 7.9 g = 28.44 kg = 3,000 x 9.4 g = 28.2 kg. In this way, the
Aegean standard of ca. 65 g is linked indirectly with the western talent by means of the “light” or Ashdod talent. As intriguing as this interpretation is, it is clear from the Cape Gelidonya evidence that the denominations necessary for a working weight set based on a unit mass in the range of 6.5-6.8 g are lacking. We must, therefore, seek an alternate explanation for these curious denominations.

Consider now a Gelidonya sphendonoid set comprising multiples of 1, 2, 3, 5, 7, 7, 20, 30, and 50 designed for a shekel system with a unit mass of 9.4 g. How may one structure this same set to function easily also in the Aegean system based on a unit mass of ca. 65 g? Certainly, various additive combinations of the weight pieces may be used to generate most major denominations of the Aegean system, but a simpler approach based on an easily remembered pattern would be more effective. While there may be several solutions to this problem, one is suggested in table 58, which presents a hypothetical set based on a unit mass of ca. 9.4 g and its equivalent units in the Aegean system of ca. 65 g. Here, all one needs to remember is to start with the 2-shekel weight piece, which corresponds to a 1/4-unit mass, or 1/24 of a mina, in the Aegean standard. Each successive denomination of the ca. 9.4-g shekel system then corresponds to successive units in the Aegean system, until the 7-unit denominations are reached. Once there, the first 7-unit weight piece may be taken to represent the Aegean unit mass, which, when doubled (both 7-unit pieces are used), corresponds to 2 units of the Aegean system. Higher units, i.e., greater than 2 Aegean units, are then obtained by adding a 7-unit weight to the shekel multiples of 20, 30, and 50, with only the $30 + 7 = 6$ Aegean units being a markedly poor fit. Surely, other equally feasible solutions are possible, but this is one of the most basic and may be carried out simply from memory, without having to consult or memorize complex conversions.

The existence of bivalent weight sets in the Bronze Age is a relatively recent concept and it is too early to fully comprehend its ramifications and evaluate its feasibility, if any. In her study of ancient weights and weighing in Mesoamerica and the Andes, Sprager (1994) also proposes the theory of bivalence and multivalence for
Table 58. Unit attributions of the sphendonoid weights based on standard unit masses of 9.4 g and 65 g.

<table>
<thead>
<tr>
<th>Unit Attribution</th>
<th>Calculated Mass</th>
<th>Unit Attribution</th>
<th>Calculated Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.4 g</td>
<td>1/8</td>
<td>8.1 g</td>
</tr>
<tr>
<td>2</td>
<td>18.8 g</td>
<td>1/4</td>
<td>16.3 g</td>
</tr>
<tr>
<td>3</td>
<td>28.2 g</td>
<td>1/2</td>
<td>32.5 g</td>
</tr>
<tr>
<td>5</td>
<td>47.0 g</td>
<td>2/3</td>
<td>43.3 g</td>
</tr>
<tr>
<td>7</td>
<td>65.8 g</td>
<td>1</td>
<td>65 g</td>
</tr>
<tr>
<td>7 + 7</td>
<td>131.6 g</td>
<td>2</td>
<td>130 g</td>
</tr>
<tr>
<td>20 + 7</td>
<td>253.8 g</td>
<td>4</td>
<td>260 g</td>
</tr>
<tr>
<td>30 + 7</td>
<td>347.8 g</td>
<td>6</td>
<td>390 g</td>
</tr>
<tr>
<td>50 + 7</td>
<td>535.8 g</td>
<td>8</td>
<td>520 g</td>
</tr>
</tbody>
</table>

ancient eastern Mediterranean weight sets, but takes a different approach to their analysis. Instead of regarding each piece in a collection of weights simply as a denomination of one standard, or as a representative of one of a variety of standards, she formulates her hypothesis on the assumption that if balance weights were found together in a group, they most likely were used together in a simple, logical fashion to weigh according to a certain mass standard (Sprager 1994: 58). Given this, the entire Gelidonya weight assemblage would have to be viewed as a set with its own definable mathematical patterning achievable by grouping units within the assemblage. Herein lies the main difficulty with Sprager’s thesis. A weight assemblage need not necessarily represent a single set complete with all its denominations. There may be several sets involved, as we propose to be the case for both the Uluburun and Cape
Gelidonya shipwrecks, or the assemblage may comprise a collection of only certain denominations to be used in weighing specific quantities for special purposes such as taxation or appropriation of goods to temples.

Sprager turns to the domain of Old World metrology for comparative mathematical patterns. In her evaluation of the Cape Gelidonya weights, Sprager questions Bass’s conclusion that the weight assemblage represents eight distinct standards, primarily on grounds of the difficulty one would experience in trying to identify the elements constituting a particular set. This concern has already been expressed directly and indirectly by both Parise and Petruso. Sprager agrees with Petruso’s choice (1984) of the 13 Gelidonya sphendonoids as making up a specific set, and with his attempts to test mathematically the relationships among them. But she finds problematic his mathematical interpretation that the set follows the Fibonacci or additive progression (Sprager 1994: 123) and in particular the way his theory explains the irregular multiples in the Gelidonya sphendonoids as compared to the Fibonacci series. Furthermore, Petruso’s conclusion (1985: 105-106) that the Gelidonya sphendonoid set, which utilized only 8 of the 13 possible weights, is somewhat peculiar vis-à-vis other excavated sets of the period, is in Sprager’s opinion (1994: 123) far from accurate. She states, rather, that the Gelidonya set is “intriguingly representative of other ancient sets,” and lumps all 13 Gelidonya sphendonoids into a single set to demonstrate her point that these weights were not oddities, but were designed according to a carefully constructed pattern. She notes that the set’s lightest unit of 9.3 g is marked and is the smallest sphendonoid in the group. Moreover, she emphasizes the distinctness of the sphendonoid set because it includes pieces designed for use in two separate standards employed in different parts of the Mediterranean: “the Minoan mina (468.0 g) of earlier times but comparable with a Late Bronze Age standard,” and the Mesopotamian mina (501.0 g). Accordingly, Sprager’s constructed set not only represents the qedet standard, which follows the characteristic decimal progression recognized for the qedet-deben-sep system (9.3 g x 50 = 465.0 g), but
may also be interpreted as representing a distinct arithmetic progression based on a 7-unit multiple of 9.3 g, i.e., 65.1 g.

Sprager's table (1994: 127, table 15) reveals a startlingly uniform pattern for the 7-unit weight pieces. They are 1-, 4-, 9-, 14-, 21-, 28-, 35-, 42-, 49-, and 50-unit multiples of 9.3 g, or fractions and multiples of 1/7, 4/7, 9/7, 2, 3, 4, 5, 6, and 7 of 65.1 g (7 x 9.3 g). Is it possible, then, that the Gelidonya sphendonoids are bivalent or multivalent weights designed to weigh additively at least in the qedet standard of 9.3 g and in the Aegean unit of ca. 65 g? The lighter end of the mass spectrum includes what would be unusual Aegean fractionals of 1/7 and 4/7 and the odd multiple of 9/7, but with some leniency these may be viewed as weights of 1/8, 1/2, and 1-1/2 units. As such, they would be in keeping with the fractionals and multiples known for the binary patterning of the Aegean system.

This seemingly regular set, however, suffers from several problems some of which were explained above. The most serious is the selection of the individual weight pieces that make up the set. Like Petruso's ingenious additive model, Sprager's interpretation of the Cape Gelidonya sphendonoids relies exclusively on those weights identified in the final excavation report as sphendonoids. Of the 13 weights described by Bass as sphendonoids or rough sphendonoids, however, at least five are what I have designated as cylindrical and loaf-shaped subtypes. While this distinction does not have significant bearing on Petruso's interpretation, it has severe ramifications for Sprager's model. As the latter is based on additive values of the weights, the feasibility of its internal patterning is a direct function of the number and masses of the individual elements of the set. Therefore, if any pieces of the set of 13, interpreted as being a complete set by Sprager, are removed or exchanged, dramatic changes will result. As the 13 weights constituting her set include a few cylindrical weights, which are quite distinct in shape from the typical sphendonoids, either they should be removed, or all cylindrical weights should be incorporated into the set. Of course, short of examining the original Gelidonya material in the Bodrum Museum, neither
Petruso nor Sprager had any way of determining the precise shapes of all the weights, as neither illustrations nor photographs of all the individual weights are included in the final publication. If all the cylindrical weights had been included in Sprager's set, the patterning would certainly have been different. Also crucial to Sprager's thesis are the first three pieces in the Gelidonya sphendonoid set, whose units total 14 \((1 + 4 + 9)\), a value that corresponds fortuitously to \(2 \times 7\) units. The remaining seemingly remarkably consistent multiples of 9.3 g are obtained only because each of the next five sequentially added weights is, in fact, a 7-unit piece! If, on the other hand, the set were to include an additional weight piece, for example of 2 units, which normally would be expected in such a set (and whose existence is theorized by Petruso), the entire series would be that many units off (two in this example) the integer multiples of 7 that the set is shown to reflect. In other words, while the sum of the first three weight pieces now equals 7 \((1 + 2 + 4)\), the total of 16 units obtained by adding the first four weights in the set \((1 + 2 + 4 + 9)\) is not an integer multiple of 7.

Consequently, the 16-unit aggregate would also offset the remaining 3, 4, 5, 6, and 7 multiples of the 7-unit mass. With the introduction of a single weight, then, the seemingly regular set can be rendered invalid. Indeed, recent visits to Cape Gelidonya have produced, among the new weights, a 2-unit piece. Therefore, the additive set theory for the Gelidonya sphendonoids would have to be significantly revised, if not altogether abandoned.

Sprager's claim (1994: 127; 205, tables 35, 36) of the extraordinary versatility of the Gelidonya sphendonoid set, which she demonstrates by combining and recombining its 13 pieces to weigh the Mesopotamian mina (504.0 g) of 8.35-g shekels and the Syrian mina (567.2 g) of 11.34-g shekels, is subject to the same complications detailed above. Moreover, she states that by combining and recombining these 13 units, almost all multiple denominations of 9.3 g may be achieved. But the combination of weights required to obtain various units, such as those of the Syrian standard of 11.34 g, for example, is well beyond simple and
reasonable manipulation, and Sprager (1994: 126) herself admits it is unlikely that ancient weight sets would have required such elaborate measures.

As for the Gelidonya domed weights, Sprager's set comprises only the 16 pieces singled out by Petruso (1984: 302-303). Understandably, Petruso has constructed his domed-weight set based on only those specimens cataloged by Bass as domed. As attributions of the weights to specific shapes involve subjective evaluations, it is plausible that several more Gelidonya weights could be added to the original 16. Moreover, the five newly discovered weights include a domed weight of 47.78 g (W 26n [W 63]). As with the sphendonoid set, both considerations would alter Sprager's set and, possibly, her evaluation and interpretation.

In his study of the Cape Gelidonya domed weights, Petruso illustrates the decimal nature of the weights by selecting only the 9 of the 16 pieces that conveniently fit the decimal configuration (Petruso 1984: 303, ill. 9). Three are excluded because they are smaller than 5 units and, as such, do not serve to demonstrate the decimal structure. While admitting to an inability to explain each individual balance weight, Petruso ventures nothing as to the nature or purpose of the remaining four that do not fit the decimal model. Sprager, on the other hand, uses all 16 domed weight pieces in her additive-set interpretation. She acknowledges the far greater complexity of using the domed set, no doubt due partly to the larger number of individual pieces involved, but prefers to evaluate all 16 weights as members of a single set rather than as elements of two or more sets. Unlike the sphendonoids, the domed weights do not include a designated piece representing the standard unit mass. Consequently, Sprager proposes a standard based on a unit mass of 7.2 - 7.5 g, values that bracket the "Phoenician shekel" of 7.3 g derived by Bass. She concludes that the domed set was also designed on much the same principle as the sphendonoid set and reveals a 7-unit progression up to at least 49 units, after which there is a notable shift (Sprager 1994: 133-34).
It is clear from our analysis that both the sphendonoid and domed weights (truncated spheres) from Cape Gelidonya included major denominations in the vicinity of 9.4 g. Both shapes represent the same basic standard with a primary mathematical structure based on the decimal system. Beyond morphology, what distinguishes the two groups is the numerical progression of their units, which, while decimal in nature, incorporates odd multiples that cannot be readily explained. In the sphendonoid group, the unusual multiples take the form of a 6-unit weight and 7-unit weights, in the domed group (truncated cones and lentoids) 4-, 6-, and 8-unit weights, if they are assumed to be based on a unit mass of ca. 9.4 g. While certain hypotheses have been advanced to explain some of these peculiar units, including a provocative one based on generating the set's multiples according to the Fibonacci series, re-examination of the available evidence, including balance weights recently discovered, indicates that such interpretations do not sufficiently explain these peculiar weight pieces.

Much of our effort in this study has been devoted to a thorough presentation of the metrological evidence from both shipwrecks in order that future researchers have complete and accurate data. Additionally, we have reviewed the material evidence and the literature and developed a model of our own design. While the proposed new model addresses the basic functioning of the two weight groups, additional sub-models have been proposed to explain the occurrence of unusual and impractical multiples. Accordingly, the Gelidonya weights appear to have been restructured, by the addition of unusual multiples to a decimally configured set, to produce bivalent sets. Thus, with certain restrictions, these sets could function within standards other than the one for which they were designed. The sphendonoid sets include 7-unit multiples that correspond to a mass of ca. 66 g (the average value of W 35n [W 32], W 39n [W 33], W 36n [W 34], W 37n [W 35], W 38n [W 36], and W 40n [W 38]), which approximates the unit mass of the Aegean standard. One explanation for this situation could be that at about the time that the Gelidonya ship sank, the Aegean mass system was making itself strongly felt in the Levant. This would have been especially true of
Cyprus, which was subjected to strong influences from the Aegean during the thirteenth century B.C.E. and eventually colonized by Aegean settlers during the third quarter of the twelfth century B.C.E.

To sum up, there appear to be only two major standards represented in the Cape Gelidonya weight assemblage, one based on a unit mass of ca. 9.4 g and the other on one of 7.1 g - 7.3 g, with an additional standard of ca. 8.3 g possibly represented by a single weight piece. There are two primary shape groups, the sphendonoid and the domed, and the standard unit mass of ca. 9.4 g is represented in both the sphendonoids and the domed sets. In contrast to the Uluburun assemblage, however, where specific weight shapes denote specific functions (i.e. sphendonoid sets were designed for weighing small quantities with denominations of up to 10 units, the domed sets for bulkier merchandise with denominations of up to 100 units), the Cape Gelidonya sphendonoids and domed shapes designate differently factored sets.

The Cape Gelidonya domed weights of truncated-sphere shape, with their standard unit mass of ca. 9.4 g, represent typical decimally configured sets with the usual 1-, 2-, 3-, 5-, 10-, 20-, 30-, and 50-unit multiples, while the sphendonoid sets (capable of weighing the same mass as the domed sets) are also each configured to incorporate the standard decimal multiples, except for the 10-unit pieces, which are each replaced by two 7-unit pieces. This configuration of the sphendonoids is provisionally interpreted as an attempt to impart to the sphendonoid sets a bivalent capability, whereby weighing could be conducted in standards based on unit masses of ca. 9.4 g and ca. 65 g. While the great majority of the Cape Gelidonya balance weights conform to a standard unit mass of ca. 9.4 g, additional weights of relatively irregular shapes and craftsmanship are more difficult to interpret, although most appear to point to a standard unit mass in the vicinity of ca. 7.1 g to 7.3 g.

The foregoing are admittedly only the major patterns, and we cannot claim to have explained each individual balance weight. It is hoped that better interpretations will follow quickly and partly or completely supplant the explanations offered here.
CHAPTER V
CONCLUSIONS

The weight assemblages from the Late Bronze Age shipwrecks at Uluburun and Cape Gelidonya, studied in detail by an intuitive analysis followed by one based on quantal searches (Kendall’s statistic), have revealed convincingly that the great majority of weights from both ships are decimally structured and conform to a standard unit mass in the vicinity of 9.3 g.

Immediately apparent is the sheer number of weight pieces involved, a total of 149 specimens from the Uluburun ship and 62 from Cape Gelidonya. The assemblage from Uluburun certainly represents the largest single collection of Late Bronze Age weights from a sealed context that saw concurrent use. Also striking is the technical diversity evident among the weights in each assemblage. While that of Uluburun appears to be a better crafted and typologically more homogenous group, several specimens from Cape Gelidonya are remarkably well crafted and are among the finest of both assemblages. Conversely, the Uluburun weights include specimens that to the untrained eye appear to be no more than chunks of raw hematite, while only one such specimen (now lost) is recorded for the Cape Gelidonya assemblage, even though the latter also incorporates several roughly shaped weights that appear to be incompletely finished specimens.

The great majority of the weights in the two assemblages fall into two main shape groups: sphendonoid and domed. The standard unit mass of ca. 9.3 g is common not only to both shipwreck assemblages, but also to the two shape groups. If these two major weight shapes represent the same mass standard, the same mathematical system, and the same denominations, why, then, did the ancient lapidaries invest so much effort in making morphologically distinct shapes, when the uses of these weights presumably did not differ considerably?

The primary purpose of this study has been to address this question in addition
to determining the mass standards represented by the weight assemblages. First, let us consider the earlier Uluburun assemblage. The majority of its weight pieces are sphendonoids. Intuitive and statistical analyses revealed at least three, and possibly four, separate standards represented among the sphendonoids. These standards are based on unit masses of ca. 9.3 g, ca. 8.3 g, ca. 7.4 g, and possibly also on ca. 10.5 g, the latter represented by only a few pieces. The overwhelming majority of the sphendonoids, however, conform to the standard unit mass of ca. 9.3 g, represented by no less than four complete sets with integer denominations. The standards of ca. 8.3 g and ca. 7.4 g are represented by only a single, nearly complete, set each (there may be a second, incomplete set for the ca. 8.3 g standard). The Uluburun domed weights, on the other hand, conform almost exclusively to the ca. 9.3 g standard.

An immediately obvious difference between these two shape groups is the absence of denominations greater than 10 units among the sphendonoids while the domed weights incorporate specimens of up to 100 units. Also, fractional denominations make up only 10% of the domed weights, while they make up 21% of the sphendonoids (for all mass standards represented), where they include lighter (smaller) denominations of 1/6, 1/5, and 1/3 not found among the domed weights. Finally, five of the hematite sphendonoids have been provided with lead plugs for the fine adjustment of their masses, while no such lead plugs exist among the domed weights.

It seems, then, that the use of the Uluburun sphendonoids were used mostly for the accurate weighing of small or light objects, almost certainly of high value, such as precious metals, semi-precious stones, spices, and the like, while the domed weights were used in everyday weighing involving bulk merchandise that did not require such great accurate mensuration. On the Uluburun ship, therefore, the shapes of the weights were indicators of their accuracy (or mass range), hence the purpose for which they were intended. There is no discernible and consistent distinction among the Uluburun sphendonoids to suggest that weight sets of different mass standards
were crafted to different shapes to facilitate their identification or separation.

Precious metals are represented on the Uluburun ship by pieces of finished and scrap jewelry of gold and silver, and by others that had been melted down into lumps. Pieces or sections have been cut from some of the gold and silver objects, indicating that they were used as bullion in trade transactions, and the sphendonoid weights would have been ideal for weighing these valuable metals. Spices, including sumac, coriander, and black cumin (nigella) were also present in some quantity, as were opercula mostly from murex seashells (probably an ingredient for incense), almost all of which must have also been weighed with the small sphendonoid weights and the pan-balances carried on the ship. It is possible that semi-precious stones in the form of agate and carnelian beads, and perhaps even the glass beads found by the thousands on the site, were traded by weight.

The merchandise on board that might have been weighed with the heavier domed weights include foodstuffs such as olives, fruit (pomegranates, figs), nuts (almonds, pine nuts), perhaps grain (wheat and barley), and small pieces of copper and tin, the hippopotamus and elephant ivory (although they may have been only counted rather than weighed), and perhaps the smaller glass ingots. One should not forget that these weights would have been needed by the merchants also to buy goods and provisions at ports of call. Using mass standards that they were intimately familiar with would have greatly facilitated such transactions, as they do for us today. For example, when buying merchandise or produce in a foreign country, it is difficult if not impossible to comprehend the weighed amounts involved without converting the foreign mass value into our own. The situation is even more complicated with the cost of the merchandise, which we may tackle with pocket calculators to ease the burden of converting the various currency values into that of our own. Quantities may be understood best, therefore, when they are expressed in units or standards one is accustomed to using; otherwise they are usually incomprehensible and meaningless. For this reason, I believe that ancient weight sets were highly personalized and valued
tools that merchants were intimately familiar with. They would use these personal weights exclusively when weighing a certain quantity of merchandise for trade and weigh again, with their own sets, the amount of merchandise received in return. Similarly, the merchant with whom the trade took place would do the same with his own set of weights. Consequently, during such transactions involving two merchants, each equipped with their respective weight sets, whether conforming to the same standard or not, the deliberate use of fraudulent weights would not have been an issue. Merchandise or produce sold to consumers who could not check the quantity received, on the other hand, may have been another story. Because a good case can be made for merchants generally trading with their own weight sets based on mass standards to which they were most exposed, I believe that weights are crucial in indicators of nationality of the merchants who used them. In other words, weight sets should be considered as and evaluated with the group of artifacts interpreted as personal effects.

As such, it seems quite clear that the merchants on the Uluburun ship were most comfortable with a weight system based on a unit mass of ca. 9.3 g. A few other small sets are also present, but they are insignificant in number and probably represent assayers' sets or sets for use mostly in simple conversions of standards. Because the standard based on a unit of ca. 9.3 g was most extensively used along the Syro-Palestinian coast, especially in Syria, and on Cyprus, its occurrence on the Uluburun ship denotes the presence of Syrian or Cypriot merchants aboard. However, the presence or absence of certain mass standards on a ship does not necessarily indicate the anticipated itinerary or the traveled route of a ship, as it would be unlikely for a merchant to conduct trade with his foreign counterparts by using foreign mass standards rather than the ones he was intimately familiar with. It is for precisely this reason that cosmopolitan trade centers are likely to reveal the presence of foreign mass standards. Weights from Ras Shamra/Ugarit, one of the most active maritime centers of the Late Bronze Age Mediterranean, for example, have revealed at least five different mass standards (Courtois 1990: 120), including the Aegean standard. The
use of native mass standards in trade, standards sometimes associated only with specific commodities, has been responsible for the introduction of various foreign standards to a region, especially through coastal cities. This has occurred even until recent historical times, when it would seem likely that mass standards were well established. For example, the port towns of New Spain (Mexico and neighboring lands) absorbed and dealt with a plethora of local weight standards brought by ships and traders from distant Cuba, Peru, and the Philippines for measuring commodities such as tobacco, wax, cloth, porcelain, pepper, gum, etc. (Carrera Stampa 1949). In this light, that the Aegean mass standard is not represented as a weight set among the Uluburun assemblage, even though at least two Mycenaean were on board, may at first seem puzzling. This situation may be easily explained, however, by pointing out that the Uluburun ship almost certainly originated on the Syro-Palestinian coast or Cyprus and was manned with merchants and crew from those regions. The Mycenaean on board, on the other hand, were probably officials or envoys, not merchants, accompanying a ship laden with an immensely valuable cargo (almost certainly a royal shipment) back to their home port. On reaching the port of destination, the cargo and other merchandise on the ship undoubtedly would have been subjected to precise tallying and weighing with weights based on the Aegean mass standard.

With regard to the different functions assigned to weights of different shapes, the Cape Gelidonya assemblage of about a century later seems to be another matter. Here, the domed weights are in the majority, but both the domed and the sphendonoid weights are capable of weighing in the same mass range because the heaviest weight pieces of 50 units (1 mina) are found in both groups, although there are more among the sphendonoids. There is only a single fractional denomination among the Cape Gelidonya weights, and it is a domed specimen, but it is likely that some of these small pieces are still on the sea bed. The sphendonoid weights seem to incorporate the decimally structured norm based on a unit mass of ca. 9.3 g and the same standard is
represented among the domed weights, though some irregularly shaped domed specimens appear to conform to a standard unit mass of ca. 7.1 g to 7.3 g. Further, no Gelidonya weight bears evidence of a lead plug that would have allowed for adjustment of its mass.

For the Cape Gelidonya weights, then, it would appear that unlike those from Uluburun, different shapes do not imply different purposes. This, however, is not the case: we propose for the Cape Gelidonya sphendonoids a mass system not archaeologically documented elsewhere. There are no 10-unit weight specimens among the sphendonoids, but there are six 7-unit pieces of ca. 9.3 g each, a denomination not normally useful and not found in other decimal sets. In this study, these 7-unit denominations are hypothesized as being incorporated into the sets to render the Cape Gelidonya sphendonoids bivalent. That is, the sphendonoids could have been used to weigh merchandise according to a standard unit mass of ca. 9.3 g and to one of ca. 65 g, and to convert between them. All three sphendonoid sets from Gelidonya appear to conform to this scheme. Yet this is not to say that the Cape Gelidonya sphendonoids represent weight sets based on the Aegean standard unit mass of ca. 65 g. On the contrary, quantal analysis has demonstrated that the standard unit mass for these sphendonoids is ca. 9.3 g. With the exception of the replacement of the 10-unit pieces, normally incorporated into an otherwise typical decimal set, with those of 7 units, these sets basically conform to a decimal substratum rather than to the binary substratum of the Aegean mass standard. What precipitated this situation, if indeed it did occur, may never be known for certain, but perhaps something may be said for a greater influence exerted by the Mycenaean, who began increasing their presence in the eastern Mediterranean during the thirteenth century B.C.E. and established a permanent presence on Cyprus early in the twelfth century B.C.E. The standard of mass used in the Aegean has been determined to conform to a value just under 61 g, a value that is suspiciously close to the second standard unit mass hypothesized for the Cape Gelidonya weights. When the use of Aegean weight sets
would have sufficed, that this standard appears to have been incorporated into Near
Eastern weight systems that had been in use in the region for centuries, could be taken
to reflect an adaptation to this change in the socio-political climate of the eastern
Mediterranean. Nevertheless, the overwhelming representation of a standard based on
a unit mass of ca. 9.3 g, with additional sets probably conforming to a unit mass of ca.
7.1 g to 7.3 g, may be taken as a clear indication that the seafaring merchants and
smiths on board the Cape Gelidonya ship in all likelihood originated on the Syro-
Palestinian coast or Cyprus.

The two diachronic weight assemblages at Uluburun and Cape Gelidonya
reveal the overwhelming presence of a standard based on a unit mass of ca. 9.3 g.
What change, if any, can be observed in the value of the standard unit mass during the
century separating these shipwrecks? In the Uluburun assemblage, the intact
sphendonoids yield for the unit mass an average value of 9.35 g and a weighted
average of 9.25 g, while the intact domed weights yield values of 9.34 g and 9.23 g,
respectively. The sphendonoids from Cape Gelidonya, which were separated into
three sets, yield for the intact weights of typical, cylindrical, and loaf-shape, average
values of 9.34 g, 9.55 g, 9.56 g, and weighted average values of 9.43 g, 9.46 g, and
9.24 g, respectively, while the intact domed weights (for both the typical and flattened
truncated spheres) yield an average value of 9.42 g and a weighted average value of
9.32 g.

These data seem to indicate a small shift in the value of the unit mass from ca.
9.35 g (9.24 g weighted average) to ca. 9.47 g (9.36 g weighted average; both of the
latter values incorporate the averages of all four weight sets). Therefore, the value of
the unit mass, as revealed by the Cape Gelidonya weights, increases by about 0.12 g in
the century following the sinking of the Uluburun ship. Whether this represents a
deliberate efforts, or seems to occur only because the Cape Gelidonya weights, unlike
those of Uluburun, do not incorporate precision weights, is difficult to ascertain. If a
shift toward a heavier norm was indeed intentional, then it would appear to be
consistent with the economic stagnation and political turmoil that prevailed in the eastern Mediterranean during the end of the thirteenth century B.C.E., and which saw at the beginning of the twelfth century B.C.E. the destruction of most Bronze Age empires (except Egypt) and city polities. Under these circumstances, in keeping with notions of economic depression, one would expect to see in the value of the unit mass an inflation or increase. Whether such a trend is to be equated with the slight shift observable in the unit mass of the Syrian/Ugaritic shekel, according to the evidence from the two shipwreck assemblages, is difficult to establish with certainty, but the potential value of diachronic studies like the foregoing seems clear and encouraging.
REFERENCES

Aharoni, Y.

Albright, W.F.

American Foundrymen's Society

Arnaud, D.

Arnaud, D.; Calvet, Y.; and Huot, J.-L.

Artzy, M.

Åström, P., and Nicolaou, I.

Barrois, R.P.A.
1932 La métrologie dans la Bible. *Revue biblique* 41: 50-76.

Bass, G.F.

Verlag.


Bass, G.F; Pulak, C.; Collon, D.; and Weinstein, J.


Ben-David, A.


1979 The Philistine Talent from Ashdod, the Ugarit Talent from Ras Shamra, the ‘Pym’ and ‘N-S-P’. *Ugarit Forschungen* 11: 29-45.

Berriman, A.E.


Boardman, J.

Böckh, A.

Braun-Holzinger, E.A.

Breglia, L.


Broadbent, S.R.

Brovarski, E.; Doll, S.K.; and Freed, R.E.

Brunton, G., and Engelbach, R.
1927 Gurob. London: British School of Archaeology in Egypt.

Buchholz, H.-G.

Buchholz, H.-G., and Karageorghis, V.

Carrera Stampa, M.
1949 The Evolution of Weights and Measures in New Spain. The Hispanic

Cartland, B.M.

Caskey, J.L.

Castle, E.W.

Catling, H.W.

Cenival, J.-L de

Černy, J.

Chabas, F.
1861  Notes sur un poids égyptien de la Collection de M. Harris d'Alexandrie. Revue archéologique 3: 12-17.


Chavane, M.-J.

Cherry, J.
Courtois, J.-C.


Davis, N. de G.


Dayton, J.

Decourdemanche, J.-A.

Dikaios, P.

Diringer, D.
1942 The Early Hebrew Weights Found at Lachish. *Palestine Exploration Quarterly* 74: 82-103.

Dow, S.

Ducros, H.-A.

Duell, P.

Dunand, M.

Encyclopedia of the Holy Land

Eran, A.
Eran, A., and Edelstein, G.

Evans, A.J.

Fischer, P.M.
1980 The Use of a Metal Detector in Archaeology. Opuscula Atheniensia 13.9: 149-53.

Garrard, F.T.

Glanville, S.R.K.

Glotz, G.

Gray, J.

Guy, P.L.O., and Engberg, R.M.

Hamilton, R.W.

Haldane, C.

Hayes, W.C.  

Head, B.V.  

Heltzer, M.  

Hemmy, A.S.  


Higgins, R.A.  

Hocker, F.  

Hough, W.  

Hudson, D.T.  
Hultsch, F.


Hundt, H.-J.

Huot, J.-L.; Bachelot, L.; Braun, J.-P.; Calvet, Y.; Cleuziou, S.; Forest, J.D.; and Seigne, J.

James, F.W., and McGovern, P.E.

Janssen, J.J.

Jidejian, N.

Johnson, J.

Judson, L.V.
Karageorghis, V.


1973 *Cyriote Antiquities in the Pierides Collection, Larnaca, Cyprus*. Athens: Ekdotike Athenon S.A.


Karwiese, S.

Kemp, B.J.

Kendall, D.G.

Kisch, B.

Kletter, R.

Kozloff, A.P., and Bryan, B.M.
Lagarce, J.

Laing, J., and Rolfe, R.T.

Lamon, R.S., and Shipton, G.M.

Lehmann-Haupt, C.F.


Liverani, M.


Loud, G.

Macalister, R.A.S.

MacCown, D.E, and Haines, R.C.
Marinatos, S.

Masson, E.

Michailidou, A.

Mills, J.S., and White, R.
1989 The Identity of the Resins from the Late Bronze Age Shipwreck at Ulu Burun (Kas). Archaeometry 31: 37-44.

Montgomery, J.A.

Newberry, P.E.

Neugebauer, O.

Parise, N.F.


1970-1971 Per uno studio del sistema ponderale ugaritico. Dialoghi di


Payton, R.

Pendlebury, J.D.S.

Persson, A.

Petrie, W.M.F.
1920 Prehistoric Egypt; Corpus of Prehistoric Pottery and Palettes. London: British School of Archaeology in Egypt.

1926 Ancient Weights and Measures. London: British School of Archaeology in Egypt.

1930 Beth Pelet I. London: British School of Archaeology in Egypt.


Petruso, K.M.


1978a Marks on Some Minoan Balance Weights and Their Interpretation. Kadmos 17: 26-42.


Pilcher, E.J.


Powell, M.A.


Pritchard, J.B.


Pulak, C.

1988  The Bronze Age Shipwreck at Ulu Burun, Turkey: 1985 Campaign.


Sakellarakis, I.


Sams, G.K.


Sarton, G.


Sayce, A.H.


Schaeffer, C.F.-A.


Schiaparelli, E.

Schumann, W.

Scott, R.B.Y.


Segrè, A.


Shany, E.

Skinner, F.G.


Smith, W.S.
1942  The Origin of Some Unidentified Old Kingdom Reliefs. *American

South, A.K., and Todd, I.A.  
1985 In Quest of Cypriote Copper Traders. Excavations at Ayios Dhimitrios. Archaeology 38.5: 40-47.

South, A.K.; Russell, P.; and Keswani, P.S.  

Sprager, D.H.  

Stieglitz, R.R.  

Sundwall, J.  

Unger, E.  

Valbelle, D.  

Valmin, M.N.  

Vercouetter, J.  
Viedebanttt, O.


von Alberti, H.-J.

von Bergmann, E.

Warnock, P., and Pendleton, M.

Warren, C.

Weigall, A.E.P.


Wiedemann, H.G., and Bayer, G.

Yadin, Y.; Aharoni, Y.; Amiran, R.; Dothan, T.; Dunayevsky, I.; Perrot, J.

Yeivin, S.
Yon, M.  

Zaccagnini, C.  


VOLUME II
APPENDIX A

KENDALL'S FORMULA

For the purpose of studying metrological data through a non-inductive approach, Kendall (1974) has proposed a most eloquent method of analysis. Kendall’s work was inspired by and based upon the contributions of statisticians searching in the 1970s for a unit of length, the so-called “megalithic yard,” the supposed span on which the layout of megalithic monuments in the British Isles was based. In his attempt to isolate standard units of balance weights and lengths used in Minoan palatial architecture, Cherry (1983) was the first to apply Kendall’s statistic (formula) to prehistoric Mediterranean material. The populations from which he derived his standards, however, were small, and Cherry himself rightly cautioned that for his conclusions on the existence of the Minoan foot to be tenable, many more measurements of palatial architecture were needed. Petruso (1992: 71-75) has explained the mechanics of Kendall’s statistic in great detail. But, for the purpose of our study, it will be helpful to review the formula briefly and illustrate its workings with our own set of hypothetical data.

Kendall proposed the following statistic:

\[ \phi (\tau) = \sqrt{\frac{2}{N}} \sum_{j=1}^{N} \cos (2\pi \frac{X_j}{\tau}) \]

where \( \phi (\tau) \) is a calculated error term for a tested unit value, or quantum (the more positive the error term, the more likely it is the tested unit will occur), within a population comprising \( N \) elements; \( X_j \) is a single observation, or the value of each element in the population; and \( \tau \) is the reciprocal of the tested quantum, or \( 1/q \). The term \( \frac{2}{N} \) is a factor that indexes the error term \( \phi (\tau) \) to the size of the population. For a population comprising elements of non-quantal nature (values that are not perfectly divisible by the unit value), the error term \( \phi (\tau) \) will tend toward zero and may have a
negative value. Conversely, for a population comprising quantal elements, the error term $\phi(\tau)$ will be relatively high and positive in value. The maximum value of $\phi(\tau)$ for a perfectly quantal population or set, that is, a set for which every observation $X$, or element in the set, is divisible by a single quantum $q$ without remainder, is determined by the number of elements in the set. The greater the population, the higher the $\phi(\tau)$. Petruso (1992: 73) demonstrates that for a perfectly quantal population, the maximum value possible for $\phi(\tau)$ is determined simply from Kendall's formula:

$$\phi(\tau) = \sqrt[2]{1/N} \sum_{j=1}^{N} \cos(2\pi X_j \tau)$$

where the term $X_j \tau$ will always be an integer $N$. Because $\cos(2\pi N) = N$, the formula reduces to:

$$\phi(\tau) = \sqrt[2]{1/N} (N).$$

Accordingly, for a population of 50 elements, $\phi(\tau) = 10$ and for a population of 125 elements, $\phi(\tau) = 15.8$.

While the procedure described by Kendall's statistic is itself straightforward, it is most tedious and best applied to large populations only with the aid of computers. As summarized by Petruso, Kendall's approach is best suited to the analysis of something like a group of balance weights suspected to be quantally configured. Below, a group of such weights with $n$ elements ($X_1, X_2, \ldots, X_n$) will be tested for possible quantal values ($q$) of the standard unit mass represented by the set. The most likely standard unit mass for the population will be the value of $q$ that returns the highest positive value for the error term $\phi(\tau)$. Thus the quantum with the highest positive value for $\phi(\tau)$ will correspond to the most likely or best common denominator for the set. It should be noted, however, that this number need not necessarily correspond to the standard unit mass of the set, but possibly to a fraction or multiple thereof, especially if the quantal search has been initiated at a value lower
or higher than the set's standard unit mass.

In order to demonstrate the great potential of Kendall's statistic for quantally configured archaeological data, balance weights in this case, and to address certain aspects or difficulties encountered in interpreting the results, it will be best to consider simplified examples using hypothetical data. For this purpose, let us conjure three populations corresponding to three sets of balance weights. Furthermore, let the first set be perfectly quantal, that is, consisting of elements that are divisible by a single quantum (i.e., 1/3-unit of 3.1 g) without remainder, and let the second set be perfectly quantal, too, with respect to its standard unit mass, but not to its fractions. Let the first two sets also incorporate an equal number of elements, while the third set, also perfectly quantal, will comprise fewer elements. In order to avoid any ambiguity in the results of our quantal searches, the elements \( X_j \) constituting each set have been carefully selected to preclude the occurrence of equivalent quanta. In other words, each balance weight \( X_j \) of set 1) of one set differs in absolute mass from each balance weight \( X_j \) of set 2) in the second set, and so on. Accordingly, our three sets are given in table 59.

It will be noted that the first two sets, each comprising 18 elements or balance weights, appear to be perfectly quantal (i.e., integer) multiples, except for the sets' fractional units. The third set, with only 16 balance weights, is perfectly quantal, as its unit of 12.3 g can be divided into every other element in the group without remainder. If this is indeed the case, then we should expect a very high positive value for the error term \( \phi(\tau) \) at the quantum that corresponds to the standard unit mass or its fraction(s).

The maximum \( \phi(\tau) \) expected for the first two sets, then, is

\[
\phi(\tau) = \sqrt{\frac{2}{N}} \langle N \rangle = \sqrt{2/18 \times 18} = + 6.000
\]

and for the third set,

\[
= \sqrt{2/16 \times 16} = + 5.657.
\]
Table 59. Quantally configured hypothetical sets based on standard unit masses of 9.3 g, 8.4 g, and 12.3 g.

<table>
<thead>
<tr>
<th>No.</th>
<th>Set 1 Standard Unit Mass 9.3 g</th>
<th>Set 2 Standard Unit Mass 8.4 g</th>
<th>Set 3 Standard Unit Mass 12.3 g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass</td>
<td>Units</td>
<td>Mass</td>
</tr>
<tr>
<td>1</td>
<td>3.1 g</td>
<td>1/3</td>
<td>2.1 g</td>
</tr>
<tr>
<td>2</td>
<td>6.2 g</td>
<td>2/3</td>
<td>4.2 g</td>
</tr>
<tr>
<td>3</td>
<td>9.3 g</td>
<td>1</td>
<td>5.6 g</td>
</tr>
<tr>
<td>4</td>
<td>18.6 g</td>
<td>2</td>
<td>8.4 g</td>
</tr>
<tr>
<td>5</td>
<td>27.9 g</td>
<td>3</td>
<td>12.6 g</td>
</tr>
<tr>
<td>6</td>
<td>37.2 g</td>
<td>4</td>
<td>16.8 g</td>
</tr>
<tr>
<td>7</td>
<td>46.5 g</td>
<td>5</td>
<td>25.2 g</td>
</tr>
<tr>
<td>8</td>
<td>55.8 g</td>
<td>6</td>
<td>33.6 g</td>
</tr>
<tr>
<td>9</td>
<td>65.1 g</td>
<td>7</td>
<td>42.0 g</td>
</tr>
<tr>
<td>10</td>
<td>74.4 g</td>
<td>8</td>
<td>50.4 g</td>
</tr>
<tr>
<td>11</td>
<td>83.7 g</td>
<td>9</td>
<td>58.8 g</td>
</tr>
<tr>
<td>12</td>
<td>93.0 g</td>
<td>10</td>
<td>67.2 g</td>
</tr>
<tr>
<td>13</td>
<td>139.5 g</td>
<td>15</td>
<td>84.0 g</td>
</tr>
<tr>
<td>14</td>
<td>186.0 g</td>
<td>20</td>
<td>126.0 g</td>
</tr>
<tr>
<td>15</td>
<td>279.0 g</td>
<td>30</td>
<td>168.0 g</td>
</tr>
<tr>
<td>16</td>
<td>372.0 g</td>
<td>40</td>
<td>252.0 g</td>
</tr>
<tr>
<td>17</td>
<td>465.0 g</td>
<td>50</td>
<td>420.0 g</td>
</tr>
<tr>
<td>18</td>
<td>930.0 g</td>
<td>100</td>
<td>840.0 g</td>
</tr>
</tbody>
</table>

Figures 22-24 show the plotted results of the quantal searches for all three sets.

Tabulated below (table 60), in descending order, are the ten highest \( \phi (\tau) \) values for each set and their corresponding quanta.

As is to be expected, \( \phi (\tau) \) for the first set is +6.0, and +5.657 for the third
Fig. 22. Plotted results of Kendall’s statistic for a quantally configured hypothetical set based on a standard unit mass of 9.3 g.

Fig. 23. Plotted results of Kendall’s statistic for a quantally configured hypothetical set based on a standard unit mass of 8.4 g.
Fig. 24. Plotted results of Kendall’s statistic for a quantally configured hypothetical set based on a standard unit mass of 12.3 g.

Table 60. Peak values corresponding to the most likely quanta represented among the quantally configured hypothetical sets based on standard unit masses of 9.3 g, 8.4 g, and 12.3 g.

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Set 1 Standard Unit Mass 9.3 g</th>
<th>Set 2 Standard Unit Mass 8.4 g</th>
<th>Set 3 Standard Unit Mass 12.3 g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantum</td>
<td>Error Term</td>
<td>Quantum</td>
</tr>
<tr>
<td>1</td>
<td>3.1</td>
<td>$\phi (\tau) = + 6.000$</td>
<td>2.1</td>
</tr>
<tr>
<td>2</td>
<td>9.3</td>
<td>$\phi (\tau) = + 5.000$</td>
<td>4.2</td>
</tr>
<tr>
<td>3</td>
<td>46.5</td>
<td>$\phi (\tau) = + 2.528$</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>23.2</td>
<td>$\phi (\tau) = + 2.114$</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>4.7</td>
<td>$\phi (\tau) = + 2.058$</td>
<td>42.0</td>
</tr>
<tr>
<td>6</td>
<td>92.85</td>
<td>$\phi (\tau) = + 1.966$</td>
<td>6.0</td>
</tr>
<tr>
<td>7</td>
<td>15.5</td>
<td>$\phi (\tau) = + 1.833$</td>
<td>60.1</td>
</tr>
<tr>
<td>8</td>
<td>31.0</td>
<td>$\phi (\tau) = + 1.706$</td>
<td>14.0</td>
</tr>
<tr>
<td>9</td>
<td>66.5</td>
<td>$\phi (\tau) = + 1.377$</td>
<td>21.0</td>
</tr>
<tr>
<td>10</td>
<td>6.2</td>
<td>$\phi (\tau) = + 1.333$</td>
<td>83.90</td>
</tr>
</tbody>
</table>
set, confirming our assertion that these two sets are perfectly quantal in nature. The second set, with its highest $\phi (r)$ at only $+5.5$ instead of $+6.0$, apparently is not perfectly quantal. This result should have been anticipated, as one of the fractional weight pieces in the set, a 2/3-unit of 8.4 g, is not perfectly divisible by the first two elements in the set without remainder (i.e., 5.6 g can not be divided perfectly by 2.1 g or 4.2 g). It will be noted immediately that the most likely common denominator for each set corresponds to a value that is only a fraction of the standard unit mass pre-established for each set. In other words, the tested quanta of 3.1 g (1/3 of 9.3 g), 2.1 g (1/4 of 8.4 g), and 4.1 g (1/3 of 12.3 g) represent the best candidates for the three sets, respectively. These results clearly demonstrate that while Kendall's statistic is invaluable for determining the most likely represented common denominator for a given population, it cannot by itself determine the standard unit mass represented by the set. For that we require external evidence. In the present example, the best such evidence consists of marks on weights that denote their denominations within a particular standard.

In the first set, our unit of 9.3 g appears as the second most likely quantum, while the third quantum is five times the standard unit mass ($5 \times 9.3 \text{ g} = 46.5 \text{ g}$), the fourth is approximately two and one-half times the standard unit mass ($2.5 \times 9.3 \text{ g} = 23.25 \text{ g}$), and the fifth is approximately one-half of the standard unit mass ($0.5 \times 9.3 \text{ g} = 4.65 \text{ g}$). In the second set, we see our standard unit of 8.4 g occupying fourth place. The first, second, and third quanta correspond to 1/4, 1/2, and 1/3 of the standard unit mass, respectively. The fifth value is five times the standard unit mass ($5 \times 8.4 \text{ g} = 42 \text{ g}$). Finally, in the third set, the standard unit mass of 12.3 g is in second place, while the first, third and fourth place values correspond to 1/3, 2/3, and 2 times the standard unit mass, respectively. Of interest is the fifth place quantum of 16.4 g, which does not appear to correspond to any integral or reasonable multiple of our standard unit mass of 12.3 g. It is equivalent, however, to 1-1/3 of the standard unit mass as well as to four times 4.1 g, the most likely quantum calculated for the set. This example
cautions us in the interpretation of peak quantal values. A high ranking quantum may not necessarily correspond to an obvious multiple of a particular standard unit.

Needless to say, the fabricated nature of these data has resulted in the highest quantal peaks corresponding to fractional values of the designed standard unit masses, and in the actual standard unit masses corresponding to the quanta of the second-highest peak in two of the sets and to the fourth-highest peak in one set. With regard to archaeological material, however, the technological, economic, and preservational conditions to which any population of artifacts was subjected will affect negatively the overall "goodness-of-fit." We should not expect, therefore, that quantal searches involving ancient balance weights will even approach the results obtained in the artificially selected sets above. But, with Kendall's statistic, we can expect any set of quantally configured ancient balance weights in a reasonably good state of preservation to reveal with some accuracy the quantum on which it was based, by returning a relatively high positive $\phi(z)$ value for the relevant quantum (Petruso 1992: 73).

By the very design of our hypothetical weight sets in the examples above, we expected the quantal analysis to reflect the only standard unit mass, and/or its fractions, represented by each set. But, how would the outcome have differed had there been more than one standard unit mass in a set? Surely it is possible, even likely, that more than one mass standard was used at a particular site, especially in the case of a ship engaged in international trade. Is Kendall's statistic capable of isolating different mass standards within the same population? To approach this problem, let us use the hypothetical weight sets employed earlier, but combine the first two sets to create a new one of 36 elements ($N = 36$) that we know includes standards based on unit masses of 9.3 g and 8.4 g. To make the situation a little more realistic, and inevitably more complicated, a second combined set comprising the elements of all three sets ($N = 52$), with their standard unit masses of 9.3 g, 8.4 g, and 12.3 g, also will be analyzed. If these fourth and fifth sets comprised perfectly quantal elements,
which we know not to be the case, as non-quantal set number 2 has been incorporated into both sets, then the maximum error term $\phi (\tau)$ would be $+8.485$ and $+10.198$, respectively.

Figures 25 and 26 show the plotted results of the quantal searches for the two combined sets, and the quanta yielding the ten highest values for $\phi (\tau)$ are tabulated in table 61.

Even a cursory examination of the quantal search results reveals that Kendall's statistic is capable of efficiently isolating each standard unit and/or its fractionals. The

---

Fig. 25. Plotted results of Kendall's statistic for quantally configured hypothetical set based on combined standard unit masses of 9.3 g and 8.4 g.
Fig. 26. Plotted results of Kendall’s statistic for quantally configured hypothetical set based on combined standard unit masses of 9.3 g, 8.4 g, and 12.3 g.

Table 61. Peak values corresponding to the most likely quanta represented among the quantally configured hypothetical sets based on combined standard unit masses of 9.3 g and 8.4 g (left), and 9.3 g, 8.4 g, and 12.3 g (right).

<table>
<thead>
<tr>
<th>Peak No.</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Attribution</th>
<th>Set 4 Standard Unit Masses of 9.3 g and 8.4 g</th>
<th>Quantum</th>
<th>Error Term</th>
<th>Attribution</th>
<th>Set 5 Standard Unit Masses of 8.4 g, 9.3 g, and 12.3 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.1</td>
<td>( \phi (\tau) = +4.273 )</td>
<td>1/3 of 9.3</td>
<td>3.1</td>
<td>( \phi (\tau) = +4.002 )</td>
<td>1/3 of 9.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>( \phi (\tau) = +3.567 )</td>
<td>1/4 of 8.4</td>
<td>2.8</td>
<td>( \phi (\tau) = +2.987 )</td>
<td>1/3 of 8.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2.8</td>
<td>( \phi (\tau) = +3.531 )</td>
<td>1/3 of 8.4</td>
<td>4.1</td>
<td>( \phi (\tau) = +2.903 )</td>
<td>1/3 of 12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9.3</td>
<td>( \phi (\tau) = +2.979 )</td>
<td>9.3</td>
<td>2.1</td>
<td>( \phi (\tau) = +2.600 )</td>
<td>1/4 of 8.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4.2</td>
<td>( \phi (\tau) = +2.549 )</td>
<td>1/2 of 8.4</td>
<td>12.3</td>
<td>( \phi (\tau) = +2.316 )</td>
<td>12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>8.4</td>
<td>( \phi (\tau) = +2.430 )</td>
<td>8.4</td>
<td>24.6</td>
<td>( \phi (\tau) = +2.265 )</td>
<td>2 of 12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>46.5</td>
<td>( \phi (\tau) = +2.272 )</td>
<td>5 of 9.3</td>
<td>9.3</td>
<td>( \phi (\tau) = +2.106 )</td>
<td>9.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>42.1</td>
<td>( \phi (\tau) = +2.081 )</td>
<td>ca. 5 of 8.4</td>
<td>8.2</td>
<td>( \phi (\tau) = +1.995 )</td>
<td>2/3 of 12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>92.70</td>
<td>( \phi (\tau) = +1.765 )</td>
<td>ca. 10 of 9.3</td>
<td>65.6</td>
<td>( \phi (\tau) = +1.683 )</td>
<td>ca. 5-1/3 of 12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>23.3</td>
<td>( \phi (\tau) = +1.737 )</td>
<td>ca. 2-1/2 of 9.3</td>
<td>41.9</td>
<td>( \phi (\tau) = +1.648 )</td>
<td>ca. 5 of 8.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
plotted graphs for the combined sets (figs. 25 and 26) clearly show that Kendall's statistic essentially superimposes the results of the individual searches previously obtained for each unit set, giving distinct peaks where the initial sets also yield non-overlapping peak values and broader peaks where peaks in the initial sets are close together or partly overlap. As expected, in set 4, the highest $\phi (\tau)$ values correspond to $q_1 = 3.1$ g and $q_2 = 2.1$ g, or $1/3$ of $9.3$ g and $1/4$ of $8.4$ g, respectively, and while both peaks are quite distinct, neither is as high as the single peak each produces in its respective set, where each also corresponds to the highest-ranking quanta. Note that again our intended standard units of $9.3$ g and $8.4$ g appear somewhat farther down the list, in fourth and sixth position, respectively. For the second combined set, number 5, the highest $\phi (\tau)$ returns correspond to quantal values of $q_1 = 3.1$ g, $q_2 = 2.8$ g, and $q_3 = 4.1$ g, which represent $1/3$ of $9.3$ g, $1/3$ of $8.4$ g and, finally, $1/3$ of $12.3$ g. Again, the actual standard unit masses of $12.3$ g, $9.3$ g and $8.4$ g occupy fifth, seventh, and eighteenth places, respectively. Shifts of about one-tenth of a gram occur in some of the q values.

We have illustrated that Kendall's statistic is capable of isolating with some reliability any single quantum and its multiple or fractions, or several such quanta, in a single population. It must be remembered, however, that the statistic will not yield immediate and unequivocal results. Under most circumstances, the quanta must be thoroughly scrutinized and cautiously interpreted, as has been demonstrated here even with hypothetical data designed to provide clear and unambiguous results. This caveat is even more crucial with regard to archaeological material, where degree of preservation and other circumstances compromise the quality of the raw data. Finally, it is often difficult to interpret how statistically significant any given value for $\phi (\tau)$ is with respect to the maximum possible value, as no such cues or guidelines exist, although Petruso (1992: 72), citing Kendall, does point out that for a random population, the calculated probability that $\phi (\tau)$ will be greater than $+ 4.000$ is only $0.00032$ in 1.
APPENDIX B

CALCULATING THE ORIGINAL MASS OF A DAMAGED WEIGHT PIECE

Because precise masses of weight pieces are crucial to the determination of their underlying standard unit mass, it is extremely important that the mass of each piece be measured as accurately as possible. For this purpose, all of the weight pieces from the Uluburun and Cape Gelidonya shipwrecks were measured with an electronic balance (Ohaus Precision Plus, model TP4KD) accurate to ± 0.01 g for mass ranges between 0 g and 800 g and to ± 0.1 g in the 801 g to 2000 g range. Weighing principles and procedures for weighing pieces are discussed in Chapter I (Factors Affecting the Determination of Mass Standards).

Damaged weight pieces, on the other hand, no longer represent their originally intended masses, as pieces chipped or broken away cause them to weigh less than when first made. Conversely, those weight pieces whose surfaces bear any trace of foreign matter, such as marine encrustation, or corrosion products, could weigh heavy. Because such weight pieces would be under- or overweight, respectively, they cannot be used in statistical analyses aimed at detecting the norm to which the weights were intended to conform. As collections of assembled weights are rare finds to begin with, it is important to be able to include as many specimens of an assemblage as possible when trying to understand their mathematical structuring. For this reason, we have tried to restore the original masses of as many specimens as possible from both shipwreck assemblages.

In an effort to eliminate the problem of overweight specimens, each one was cleaned of all foreign materials and then thoroughly desalinated in distilled water until nearly all absorbed sea salts had been removed. The distilled water bath of each weight piece was changed at regular intervals until its conductivity dropped to a level of approximately 80 microsemens. For comparative purposes, it is of interest to note
that the maximum conductivity of distilled water produced in the Bodrum Museum is about 80 microseemens. All weight specimens, whether of stone, metal, or stone and metal (i.e., hematite weights with lead plugs), therefore, were desalinated to the same level of conductivity.

The calculation of a damaged weight specimen's original mass, on the other hand, is much more involved, although, in principle, the procedure is straightforward. After weighing the damaged piece in air and water to calculate the specific gravity of the material, the task is to restore as accurately as possible the chipped or broken areas on weight pieces with oil-free plasticine. Then the weight of the specimen is again measured, first in air and then in water. Measurements in water are taken with a hydraulic balance, which is simply a balance adapted to weigh objects completely submerged in water (the electronic balance we used has an attachment point for suspending objects to be weighed in water). The difference between the weight in air and the weight in water after restoration corresponds to the volume of the restored weight piece, which is then multiplied by its specific gravity (also known as the relative density). This product should correspond to the weight's originally intended mass, designated in this study as "calculated mass" and indicated by "(cal.)" following the calculated mass. These procedures are explained in greater detail below.

Density is defined as the mass of a material per unit volume and is calculated as follows:

\[
\text{density} = \frac{\text{weight of material}}{\text{volume of material}}.
\]

Specific gravity is the ratio of the weight of a material to the weight of the same volume of pure water. As pure water at 20°C and at a pressure of 1 atmosphere (sea level) weighs 1 g per cubic centimeter (cm³), specific gravity is numerically equal to density, but without the units indicated. Thus, hematite with a density of 5.2 g/cm³ has a specific gravity of 5.2, which means that it is 5.2 times as heavy as the same volume of pure water.

The mass of each specimen was measure to 1/100 of a gram, i.e., to two
decimal places, and its volume was determined by using Archimedes's principle, also known as the buoyancy process. This principle states that the buoyancy force acting on an object equals the weight of the water displaced by the object. The object whose density or specific gravity is to be determined, a weight specimen in our case, is first weighed in air and then in distilled water. The difference between the two weights corresponds to the weight of the displaced water, and hence the total volume of the weight specimen. This volume is then divided into the mass of the weight specimen taken in air to arrive at its specific gravity. Some minerals, however, naturally contain small impurities, variations in their composition, and voids or sealed gas pockets. In such cases the density values show considerable diversity. If an average published density were used to calculate a weight specimen's original mass, therefore, the result would be somewhat inaccurate. In order to avoid such a pitfall, the specific gravity of each weight piece used in this study was determined individually. This approach has allowed for a fairly accurate determination of the original mass for each weight piece. It should be noted that the density values calculated for the Uluburun and Cape Gelidonya weights varied considerably, and in the case of hematite, all values were significantly less than the average density of 5.2 - 5.3 g/cm³ cited in the literature (Schumann 1993: 104).

An example will illustrate the procedures described above. Consider sphendonoid hematite weight W 102 (KW 3315) from Uluburun, which is damaged at one extremity:

Weight in air = 91.67 g
Weight in water = 72.81 g
Volume = 91.67 g - 72.81 g = 18.86 cm³
Density = 91.67 g ÷ 18.86 cm³ = 4.86 g/cm³
Specific gravity = 4.86
Weight in air after restoration with plasticine = 91.97 g
Weight in water after restoration with plasticine = 72.94 g
Volume after restoration with plasticine = 91.97 g - 72.94 g = 19.03 cm³

Original or calculated mass = 19.03 cm³ x 4.86 g/cm³ = 92.49 g.

The damaged section of weight piece W 102 (KW 3315), therefore, has resulted in a mass loss of 1.82 g. Note also that its density has been calculated as 4.86 g/cm³, a value considerably less than 5.2 to 5.3 g/cm³. A note of caution: it is important to ensure that the weight pieces are absolutely dry and do not contain any foreign substances when weighed in air; care should be taken to completely submerge the weight piece and free all air bubbles trapped or adhering to it when weighed in water.

The same principle may also be applied to weight specimens of metal. In metal weights, however, mass and density are subject to change due to leaching and/or corrosion of the metal itself. As a result, a metal weight specimen's original density and mass cannot be as accurately determined as those of a stone weight, and the restoration of its originally intended mass has to be calculated according to average density values published for that specific metal. Density values for cast bronze vary from 8.6 g/cm³ to 8.8 g/cm³ (Laing and Rolfe 1941: 34), but, for the purposes of this study a much more conservative value of 8.3 g/cm³ has been used for the bronze weight pieces. As such, the restored masses of bronze weights are less accurate and have been designated here as "(est.)" for estimated mass. Estimates for the original mass of copper pieces cataloged as weights from Cape Gelidonya have been made with a conservative density value of 8.5 g/cm³, with average densities for sand-cast copper being in the range of 8.8 to 8.92 g/cm³ (American Foundrymen's Society 1957: 263).

When dealing with weights of composite materials such as hematite with lead plugs or bronze with lead cores, restoration of their masses to the degree of accuracy needed in this study is impossible. As the loss of mass for each material constituting the weight piece is different, especially in the case of metals, the average density of the materials cannot be used to quantify the amount of mass loss. For these reasons, we have not undertaken to restore the original mass of weight specimens made from more
than one material. This deficiency has severely limited the number of weight pieces that could be used to study several categories, the zoomorphic group being chief among them. As a result, no serious attempt has been made to study the zoomorphic group as a set.
APPENDIX C

CATALOG OF WEIGHTS FROM ULUBURUN

W 1. Stone (compact limestone) sphendonoid weight. Museum Inv. No. None Inv. No. KW 5136 M16 UL4 L 2.032; w. 0.723; h. 0.705; max. diam. of hole nearest end 0.100; min. diam. 0.099; hole depth 0.3; max. diam. of second hole 0.101; min. diam. 0.093; hole depth 0.3; center-to-center distance between holes ca. 0.13; mass 1.56 g.

Most of surface off-white with green tinge, separated from purer white portion by black vein running diagonally across base, along one base edge, and up one side diagonally; some brownish-black spotings. Complete, well preserved. Some superficial surface erosion; several minute to small pits on top and side surfaces. Two minute chips on one side near base edge.

Top view shows one side curvature fuller and more angular than other, and truncated ends, one faintly rounded. In side view, top curvature slightly angular and both ends faintly convex, each joined to base with faintly convex bevel. End view irregularly rounded with one side facet adjoining base. Flat base, notably inclined to body of weight and notably displaced toward one end, extends over about one-half of weight's length and most of width; edge rounded to fairly sharp. Moderately formed, well finished. Low to medium polish; fine polish marks over top parallel to long axis and coarser ones on one end parallel to base.

On one side near one end are two adjacent deep pits or holes, of undeterminate origin, essentially perpendicular to weight's long axis and parallel to base. Under low (10–40X) magnification, diameters appear constant throughout their lengths, not tapered.
W 2. Stone (hematite) sphendonoid weight.
Inv. No. KW 1660
L. 2.042; w. 0.655; h. 0.555; mass 1.78 g.
Brownish red with blue tinge. Incomplete, poorly to moderately preserved. Significant surface erosion, pitting, and chipping over virtually entire surface.

Top view shows long, gently curved sides, ends truncated at opposite angles. In side view, top curvature long and gentle; one of essentially straight, vertical ends joined to base by a barely convex bevel. End view shape essentially a truncated circle. Flat base covers most of length and width; edge fairly sharp. Well formed, quality of finish indeterminate; matte.
Inv. No. KW 1596 M12 UL3
L. 1.798; one end 0.724 x 0.688; other end 0.702 x 0.661; mass 2.07 g.
Dark gray. Complete, excellently preserved. Superficial surface erosion over entire weight; two minute pits near one end.

Top and side views show long trapezoid. End view shape nearly square with beveled corners. Moderately well formed and finished; matte.
Coarse, parallel abrasion marks slightly inclined to weight's long axis plainly evident over all side surfaces.
Inv. No. KW 5719
L. 1.179; w. 0.976; h. 0.992; mass 2.96 g.
Brownish red. Complete, moderately preserved. Some surface erosion and minute pitting; exfoliation at one edge. Some chipping along one edge.
Irregular cube with no right angles; four surfaces display several facets each. Poorly formed, moderately finished; matte to low polish; fine polish marks on two surfaces and some facets.
Metal (bronze) sphendonoid weight. Museum Inv. No. 27-24-86
Inv. No. KW 337 K14 LR3
L. 1.440; w. 0.859; h. 0.653; mark or depression stem l. ca. 0.258; one
crossbar l. ca. 0.432; other crossbar l. ca. 0.394; pres. mass 2.71 g (-); est.
mass 3.49 g.
Dark greenish-gray to black. Complete, moderately preserved. Superficial
surface erosion has followed thin exfoliation of nearly entire top and side
surfaces and part of base; some patches of thicker exfoliation. Small chip
on base; one crack from center of one side diagonally up to top and to one
end.

Top view shows two full side curvatures, one slightly angular, and
slightly rounded ends. Side view shows rounded top (except for mark
depression) and ends with full, angular curves, one joined to base with
convex bevel. End view shape essentially truncated circle (except for mark
depression). Flat base covers most of length and width, edge fairly sharp.
Moderately well formed, quality of finish indeterminate; matte.

A shallow impression of an I lies in the center of top surface with stem
essentially on weight's long axis; top edges of each crossbar are markedly
convex, not straight. Cross-sectional shape of each impression a broad,
shallow U with rounded, ill-defined edges.
Stone (hematite) spongeoid weight. Museum Inv. No. 26-1-94
Inv. No. KW 3212 N18 UR1
L. 1.716; w. 1.016; h. 0.875; mass 3.59 g.
Brownish red; black patches and many black speckles that scrape off.
Complete, moderately well preserved. Some surface erosion on top, base,
and side surfaces; rather large patches of deep pitting.
Top view reveals full curvatures and ends truncated at reverse angles.
Side view shows full top curvature, ends essentially straight and angled
slightly outward, each linked to base by convex bevel. End view shows
truncated circle irregularly rounded. Flat base, moderately inclined to body
of weight, reaches over most of length and width; edge fairly sharp.
Moderately formed, well finished; matte to low polish.
W 7. Metal (bronze) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 1223 M15 UR2
L. 1.920; w. 0.855; h. 0.578; pres. mass 0.82 g (-); est. mass 3.74 g.
Dark gray to black. Incomplete, moderately preserved. Surface erosion
or extremely thin exfoliation over most of weight; minute chip at one end,
a small one on base edge and a few also on top surface. Light for size.

Top view reveals one side curvature fuller and more angular than the
other; ends pointed. Side view shows top curvature flattened and becomes
nearly straight toward ends; ends pointed and each joined to base with
short, rounded bevel. End view shape somewhat irregular hemisphere.
Base over nearly all of length and entire width somewhat uneven; edge fairly
sharp. Moderately formed and finished; matte.
W 8. Metal (bronze) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 2891 J15 UR3
L. 1.793; w. 0.843; h. 0.623; mark or depression stem l. 0.559; crossbar l.
0.509; pres. mass 2.27 g (-); est. mass 3.90 g.
Various greens of copper oxidation products with small areas of brownish
reds. Complete, poorly preserved. Original surface significantly eroded and
approximately one-half exfoliated.

Top view reveals one slightly bulbous side and a more angular one,
ends slightly rounded. Side view shows top curvature fuller over one-half
of length, flatter over other; one end pointed, the other essentially straight
and vertical, each linked to base by means of barely convex bevel. End view
shape essentially truncated circle except for flattened spot on top at location
of mark. Flat base extends over nearly entire length and most of width;
edge rounded. Moderately formed, quality of finish indeterminate; matte.

Broad, shallow impression of an I lies along weight’s length, in roughly
central one-third of weight’s length. Cross-sectional shape is broad, shallow
U with rounded, ill defined edges.

Museum Inv. No. None
Inv. No. KW 4269

M16 UL2

L. 1.905; max. diam. 0.950; min. diam. 0.912; mass 3.92 g.
Brownish red; some copper and iron oxidation products. Complete,
poorly preserved. Extensive surface erosion, pitting, and chipping.

Top and side view shapes essentially rectangular with convex sides that
approach bilateral symmetry, though one end not perpendicular to long axis.
End view shape essentially circular. Moderately well formed, quality of
finish indeterminate; matte.
W 10. Stone (limonite) sphendonoid weight. 
Inv. No. KW 1583
L. 2.420; max. diam. 0.882; min. diam. 0.827; mass 4.01 g.
Darkest brown with some lighter patches, damaged areas brownish red.
Complete, well preserved. Surface erosion has exposed irregular
concentric pattern of stone’s “grain” on top surface. Minute pitting
over most of surface and three small to large patches of dense pitting near
one end. Same end exhibits medium-size chip on edge and large chip near
middle of top surface adjacent to largest pitted area. One long shallow
scratch over most of length near one edge of base.

Top and side views show gentle side and top curvatures and straight,
truncated ends. End view shape irregularly ovoid with faint flats resulting
from facets that run length of weight. One such facet that is convex over
both axes and displays rounded edges probably represents base. Moderately
formed, very well finished; low polish.
W 11. Stone (hematite) sphendonoid weight. Museum Inv. No. 16-1-94 N18 LL2
Inv. No. KW 3164
L. 2.262; w. 1.052; h. 0.763; mass 4.01 g.
Dark brownish red with darker mottling. Complete, excellently preserved.
Some minute pits in one patch on top surface; one small chip on side at base edge.

Top view shows two full side curvatures, one faintly angular, and truncated ends. Side view shows flattened top curvature and straight, vertical ends, each joined to base with faintly convex bevel. End view reveals irregular, truncated ovoid. Flat base reaches over most of length and width, edge fairly sharp. Moderately well formed, very well finished; medium polish.
W 12. **Metal (bronze) sphendonoid weight.**

Inv. No. KW 503

Museum Inv. No. 67-24-86

K15 LL3

L. 1.569; w. 0.906; h. 0.688; pres. mass 3.21 g (-); est. mass 4.07 g.

**Black.** Complete, moderately well preserved. Except for small patches on top and base, entire surface thinly exfoliated; tip of more blunt end chipped off.

Top view shows full side curvatures that approach bilateral symmetry except for two faint, diagonally opposed concavities at opposite ends. Side view reveals top fully rounded, intact end rounded and opposite end irregular and angled inward to base. End view shape barely irregular truncated circle. Flat base extends over most of length and width, edge fairly sharp. Moderately well formed, quality of finish indeterminate; matte. Fine, parallel lines and somewhat coarser, more irregular lines on preserved top surface may be tool marks left in the wax or mold.
Max. diam. 1.459; min. diam. 1.409; h. 0.822; mass 4.11 g.
Dark brownish red with some black spots, lighter brownish red and rust in damaged areas. Incomplete, moderately preserved. Appreciable surface erosion and pitting; one large chip and several smaller ones on base edge.
Circumference shape irregularly rounded, with five vestigial facets.
Cross-sectional shape truncated cone with convex sides and uneven top.
Base flat with fairly sharp edge. Moderately formed, quality of finish indeterminate; matte.
Inv. No. KW 228 O15 LR1
L. 1.680; w. 1.163; h. 0.763; mass 4.25 g.
Deepest brownish black to black. Complete, very well preserved. Minute pitting here and there; one medium-size pit on top.

Top view shape an irregular ellipse. Side view shows irregularly rounded top; one end rounded, other consist of two bevels. One end view reveals top and one side are fully, irregularly rounded, the other side nearly straight; each side linked to base by short bevel; three small facts on one end. Flat base extends over entire length and almost entire width; edge sharp. Moderately well formed, well finished; low to medium polish. One end exhibits polishing or shaping marks that are parallel to base, while similar marks on side bevel adjoining one base edge are inclined 30 degrees from base.
W 15. Stone (hematite) rectangular weight. Museum Inv. No. 49-5-90
Inv. No. KW 2032 N14 UL1
Max. l. 1.532; min. l. 1.422; max. w. 1.419; min. w. 1.123; max. h. 0.633;
min. h. 0.534; mass 4.39 g.
Brownish red with black variegations. Complete, excellently preserved.
Some superficial surface erosion on top; several minute chips on base at
edge, one medium-size chip on base at one corner.
Top view shows quadrilateral with rounded corners and two slightly
convex sides; two essentially straight sides meet at a right angle, and two
rounded sides meet at a slightly obtuse angle. Side and end views show
somewhat uneven, flat to slightly convex sloping top with rounded edges;
sides either rounded or essentially straight and vertical. Flat base covers
almost entire length and width; edge sharp. Moderately well formed, very
well finished; matte to medium polish. Faint polish marks on base over
entire width and most of length barely inclined to short axis.
Inv. No. Lot 918 K14 LR1
Preserved diam. 1.178; h. 0.691; pres. mass 1.07 g (-); est. mass 3.40 g; est.
mass after restoration 4.57 g.
Deepest green to black; associated piece deepest brownish red to black.
Incomplete, poorly preserved; some pieces reattached. Small patch thinly
exfoliated from base; thick exterior layer cracked and separated from
cracked and crumbling “core.” About one-third of diameter missing.
Circumference shape irregularly ovoid. Cross section reveals top and
side surfaces fully rounded. Base flat with fairly sharp edge. Well formed
and finished. Medium polish; many groups of minute parallel striations run
every which way over entire original surface.
Striations are probably tool marks made in the wax or on the mold.
W 17. Stone (limonite) sphendonoid weight. Museum Inv. No. 23-5-87
Inv. No. KW 955 M10 LL3
L. 1.918; w. 1.141; h. 0.921; mass 4.67 g.
Dark tannish to blackish brown and a dark brownish red patch; iron
oxidation products over much of one side. Complete, well preserved.
Some superficial surface erosion over part of one side; minute pitting over
entire surface; thin exfoliation along most of one base edge and up onto
adjacent side.
Top view shows one side curvature somewhat fuller than other; ends
truncated. Side view shows fully rounded top; one end is straight,
essentially vertical, the other barely rounded, each joined to base with short
bevel. End view shape a slightly irregular truncated circle. Base covers
most of length and width and somewhat uneven along length, flat over
width. Edge rounded to fairly sharp. Moderately well formed, well
finished; low to medium polish. Short, fine polish marks on both ends
inclined ca. 30 degrees from base, as those visible along one side near base.
Inv. No. Lot 10968 M19 UL2
L. 1.744; w. 1.561; h. 0.977; mass 4.79 g.
Brownish red with blue tinge on three surfaces; copper oxidation products
on one surface. Complete, moderately preserved. Superficial surface
erosion over entire surface; minute pitting and small and medium-size
chips on all surfaces and edges.
Irregular pentagonal form possibly with two worked surfaces,
remainder chipped and broken; all edges rounded either by wear or working.
Quality of form and finish indeterminate; matte.
Inv. No. KW 494 K14 LR1
L. 2.265; w. 1.134; h. 0.768; mass 5.38 g.
Dark brownish red. Complete, well preserved. Some superficial surface erosion. Minute pitting over most of weight; several small pits, one medium-size one on base edge at one end.

Top view shows two somewhat angular side curvatures; ends truncated, one barely rounded. Side view shows top fully rounded, ends essentially straight and vertical. End view shape a truncated circle. Flat base reaches over entire length and most of width; edge sharp. Well formed, very well finished; medium polish.
W 20. Stone (hematite) sphendonoid weight. Museum Inv. No. 5-4-88
Inv. No. KW 1425 N14 LR2
L. 2.544; w. 1.023; h. 0.792; mass 5.51 g.
Brownish red with some darker patches. Complete, very well preserved.
Superficial surface erosion and minute pitting over most of weight, with
one small pit on base edge.

Top view shows one side curvature slightly fuller than other, ends
truncated but slightly rounded. Side view reveals fully rounded top and
slightly convex ends, each joined to base with short, faint, convex bevel.
End view shape essentially a truncated circle. Base reaches over most of
length and width, flat over length, slightly concave over width; edge
rounded to fairly sharp. Well formed and finished; matte to medium polish.

Base with seven shallow, discontinuous cuts inclined slightly from
weight's short axis. Discontinuity due to slight concavity across base's
width. Four cuts appears as if made with single stroke across entire width
of base, followed by three shorter ones on same edge of base. In each
instance, shorter cuts added to same side of each longer cut.
Inv. No. KW 4323 N16 LR3
L. 2.192; w. 0.919; h. 0.838; pres. mass 5.78 g (-); est. mass 5.89 g.
Original surface black; exfoliated areas shades of copper oxidation
products. Complete, moderately preserved. Almost entire surface
eroded, exfoliated, or both.

Top view reveals both side curvatures full, but flattening toward the
more pointed of the two pointed ends. Side view shows one-half of top
fully rounded, the other less so; each pointed end joined to base with a
barely rounded bevel. End view shows truncated circle. Flat base, slightly
inclined to body of weight and moderately displaced toward one end,
reaches over about one-half of length and most of width; edge rounded.
Moderately formed, quality of finish indeterminate; matte.
W 22. Stone (ilmenite [?]) sphendonoid weight. Museum Inv. No. 54-7-92
Inv. No. KW 2899 O15 UL4
L. 2.408; w. 1.021; h. 0.823; mass 5.97 g.
Dark brownish red to black. Complete, very well preserved. Some
superficial surface erosion. Minute pitting on one side and on base, several
small scattered pits; one small exfoliated spot on top near one end.
Top view reveals one side curvature flatter and slightly less angular
than other, truncated ends faintly rounded. Side view shows gently rounded
top; one barely rounded end and one straight, nearly vertical end joined to
base by short bevel. End view shape a truncated circle with short flat near
top. Flat base reaches across most of length and width; edge fairly sharp.
Moderately formed, well finished; low to medium polish.
W 23. Stone (hematite) scarab weight. Museum Inv. No. 21-7-92
Inv. No. KW 2784 N15 LR2
L. 1.680; w. 1.338; h. 0.856; hole (front) max. diam. 0.287; min. diam.
0.260; hole (back) max. diam. 0.294; min. diam. 0.250; mass 6.04 g.

Dark brownish red with blue tinge. Complete, very well preserved.
Superficial surface erosion over entire object; one very small chip at bottom
of front hole.

Scarab that approaches bilateral symmetry over both axes.
Circumference shape an ovoid truncated at its narrow end. Lateral cross
section shows faintly convex top rounding into faintly convex sides. Flat
base reaches over entire length and width; edge sharp. Well to very well
formed and finished; matte.

Tapered holes drilled from each end after details carved run along long
axis and meet within weight. Resulting hole axis inclines slightly downward
from front to rear. Each hole slightly elliptical at exterior surface, neither
showing evidence of wear around edge.

Details of thorax, pronotum, and elytra not rendered. Head delineated
by fine incision across top and by similar incision highest across width in
anterior view. Incisions on head indicate faintly V-shaped left eye, with
right eye represented by similar but non-convergent incisions; stylized
clypeus takes form of shallow groove across head and seven irregularly
spaced notches along its anterior edge. Anterior view shows curved
horizontal incision beneath head that indicates top of both forelegs and a
lower line to delineate lower edge of right foreleg, but corresponding
incision for left foreleg not carved. In posterior view, edges of elytra (wing
covers) indicated by wide indentation at either side of rear hole, and one
nearly horizontal incision on either side of base represents lower surfaces of
hind legs. Base surface exhibits narrow, shallow groove of U-shaped cross
section around periphery.

Absence of wear marks around hole edges suggests weight not fitted
with metal suspension loop. Therefore, the preserved mass of the piece
closely approximates its originally intended mass.
Inv. No. Lot 1796 M11 LL
Max. diam. 1.885; min. diam. 1.754; h. 0.874; mass 6.12 g.
Dark brownish red with faint blue tinge. Complete, poorly preserved.
Top surface significantly pitted and eroded, “base” surface completely chipped.

Circumference shape an irregular ovoid with one short, straight length.
Cross-sectional shape approximates a truncated, asymmetrical cone, with an uneven top and most irregular base. Quality of form and finish indeterminate; matte.

Piece probably accidentally or deliberately broken off a larger weight, and ground down until desired mass and approximate shape was obtained.
Metal (bronze) sphenoid weight. 

Inv. No. KW 467 

L. 1.892; w. 0.964; h. 0.798; incised mark l. 0.591; max. w. 0.184; depth ca. 0.075; pres. mass 4.82 g (-); est. mass 6.23 g.

Various shades of green copper oxidation products; two patches of dark, gray staining, one of iron oxidation products. Complete, well preserved. Superficial surface erosion over most of weight; several minute pits and exfoliated patches.

Top view shows faintly bulbous side curvatures, one somewhat angular; one end slightly truncated, the other a rounded point. Side view reveals top also a bulbous, faintly angular curve; ends essentially straight and vertical, but round into base. End view shape a truncated circle except at mark on top. Flat base reaches over most of length and width; edge fairly sharp. Moderately well formed, quality of finish indeterminate; matte.

On top surface a straight, broad, shallow impression on weight’s long axis, commencing at about mid-length and extending toward one end. Sectional shape is a short, shallow U.
Metal (bronze) domed (?) weight. Museum Inv. No. None
Inv. No. KW 768 L15 LR3
Max. base diam. 1.378; min. diam. 1.315; max. apex diam. 0.580; min.
diam. 0.529; h. 0.974; pres. mass 1.10 g (-); est. mass 6.31 g.
Darkest gray to black. Complete, moderately preserved. Nearly all of
original surface thinly exfoliated, resulting in superficial surface corrosion
and minor pitting. One segment of pentagonal apex edge eroded. Light for
its size.
Circumference shape irregularly rounded, with two relatively straight
lengths that meet at a point at one end. Raised ridge ca. 0.1 cm. wide
extends from base edge at that point to one angle of a pentagon, from
whose other four angles similar ridges extend to base edge. Three ridges
thus join pentagon to the three angles at one end of weight. Between ridges
vertical concavities extend from edges of pentagon to base edge.
Longitudinal cross section is short, broad, truncated cone with fully rounded
base and off-center, slightly concave apex with slightly uneven surface.
Lateral cross section similar, but with nearly symmetrical sides. Quality of
form and finish indeterminate, but seems fairly good; matte.
W 27. Stone (hematite) sphendonoid weight. Museum Inv. No. 36-5-87
Inv. No. KW 966 M15 UR3
L. 2.511; w. 1.132; h. 0.932; mass 6.59 g.
Brownish red with blue tinge. Complete, poorly preserved. Some
superficial surface erosion and minute pitting; some medium-size chips on
sides and on both ends, quite large chipped areas on top and both side
surfaces.

Top view exhibits one full side curvature and one flatter, more
irregularly curved side, and truncated ends. Side view shows irregular, fully
rounded top and essentially straight, vertical ends each joined to base by
bevel. End view shows truncated circle with very irregularly rounded sides
and top. Flat base extends over most of length and width; edge fairly sharp.
Poorly formed, moderately finished; matte to low polish.

Inv. No. KW 4364  M15 LR3

Max. top diam. 1.643; min. diam. 1.597; max. base diam. 0.980; min. diam. 0.912; h. 1.459; mass 6.62 g.

Brownish red with lighter shades of red. Complete, well preserved.

Superficial surface erosion and minute pitting fairly uniform over all surfaces. Several shallow scratches and cracks, with one irregular crack across small portion of base extending partly up one side.

Circumference shape an irregular circle. Cross-sectional shape essentially an inverted truncated cone. Planes of base and top not parallel; top essentially flat, with faint but distinct edge joined to faintly convex side surface by means of short, rounded bevel. Base slightly uneven with fairly sharp edge. Well formed, moderately well finished; matte.
W 29. Stone (diorite [?]) sphendonoid weight. Museum Inv. No. 56-24-86
Inv. No. KW 469 K14 LR1
L. 2.465; w. 1.438; h. 1.142; mass 6.88 g.
Greenish gray with some dark green patches. Complete, moderately
preserved. Minute to small pits over entire surface, several of medium
size; several small to medium-size chips.
Top view shows side curvatures about equally full, one barely angular,
and ends truncated. Side view reveals top curvature somewhat angular,
with longest length barely concave; one end straight and vertical, the other
somewhat rounded, each joined to base with very short bevel. End view
shape a truncated circle, with a few flat spots on top. Flat base reaches over
nearly entire length, most of width; edge somewhat rounded. Moderately
well formed, moderately finished; matte to low polish.
W 30. Stone (hematite) sphenondoid weight. Museum Inv. No. None
Inv. No. KW 4184 N16 UL2
L. 2.397; w. 1.249; h. 0.797; mass 6.94 g.
Brownish red with blue tinge, speckles and patches of darkest brown to black. Complete, very well preserved. Superficial surface erosion and minute pitting over most of weight, especially on base, along side base edges, and at one corner of one end. One minute chip on top at edge of one end.

Top view shows one side slightly fuller than the other; ends truncated in opposite directions. Side view exhibits somewhat angular top curvature and barely convex ends angled inward to base. End view shape essentially a truncated circle. Flat base reaches over entire length and most of width; edge sharp. Well formed and finished; matte.
W 31. Stone (diorite [?]) sphendonoid weight. Museum Inv. No. 23-5-90
Inv. No. KW 1854 J17 UL1
L. 2.327; w. 1.593; h. 1.259; pres. mass 5.85 g (-) (in fragments); original
mass 7.27 g.

Dark gray with greenish tinge. Incomplete; several pieces attached.
Complete and well preserved when found. Superficial surface erosion,
minute pitting, and severe cracking over entire surface. Large portion
exfoliated at preserved end; approximately one-quarter of length fragmented
and cannot be reattached.

Top view hints that one side was slightly fuller and more angular than
the other, one end possibly slightly truncated and rounded. Side view
suggests top faceted rather than curved, with two facets evident and a trace
of a third that begins at break point; nature of ends indeterminate. End view
shape fully rounded but faintly faceted. Flat base extends over most of
width, extent of length indeterminate; edge fairly sharp. Seems to have been
moderately formed and moderately to moderately well finished; matte.

Asymmetrical profile suggest stylized duck form.
W 32. Metal (bronze) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 4424 N17 UR3
L. 2.461; w. 0.964; h. 0.797; pres. mass 5.63 g (-); est. mass 7.47 g.
Black with shades of copper oxidation products. Nearly complete,
poorly preserved. Significant surface erosion and much of surface
exfoliated.

Top view shows one side curvature slightly angular and fuller than
other, both ends pointed but one somewhat blunt. Side view reveals top
gently rounded; one end rounded and other essentially straight and vertical,
each joined to base by bevel. End view shape an irregular, truncated circle.
Flat base extends over most of length and width; edge rounded. Quality of
form and finish indeterminate; matte.
W 33. Stone (hematite) trapezoidal weight.  
Inv. No. KW 804  
L. 1.874; w. 1.556; h. 1.068; mass 7.69 g.  
Dark brownish red. Complete, moderately to moderately well preserved. Many minute and small pits; several small to medium-size chips over top surface and one large chip on base at edge. Appreciable exfoliation over both ends and base surface.  
Top view shows an irregular quadrilateral with two longer and two shorter sides, one of the latter slightly rounded. Side view reveals barely convex top, one end straight and vertical, the other irregularly convex. End view shows truncated circle roughly formed by means of seven facets, one on top and three to each side, each over entire length of weight. Flat base extends over entire length and most of width; edge fairly sharp. Poorly formed, moderately finished; low to medium polish. Polish marks, evident on all facets, inclined ca. 30 degrees to long axis.

[Diagram of stone weight]
W 34. Stone (limonite/goethite) sphendonoid weight. Museum Inv. No. 3-27-91
Inv. No. KW 2667  N15 UL3
L. 2.319; w. 1.314; h. 1.085; mass 7.75 g.
Brownish red; dark green and black mottling, both presumably staining.
Complete, very well preserved. Minute to small pits on part of base and
small patches on side surfaces.
Top view exhibits truncated ends, one somewhat rounded. Side view
shows fully rounded top and straight ends angled slightly inward, each
joined to base by a bevel. End view shape a truncated circle. Flat base
covers most of length and width, edge fairly sharp. Well formed, very well
finished; low to medium polish. Some short, broad, widely spaced polish or
abrasion marks run along length over most of sides and top, while at one
end some parallel to base and some inclined 30 degrees from it.
Stone (diorite [?]) sphendonoid weight. Museum Inv. No. 29-5-90
Inv. No. KW 1915 N12 LL1
L. 2.916; w. 1.676; h. 1.145; mass 8.01 g.
Mottled light gray and dark greenish gray. Complete, moderately well preserved. Several small to medium-size chips on or near base edge and scattered elsewhere; thin vein in stone, running around circumference near base, somewhat eroded here and there.

Top view shape very rough, oblong ellipse. Side view shows faintly faceted, but rounded top that slopes gently from one end to the other; both ends convex. End view reveals an irregular hump. Flat base extends over most of length and entire width; edge fairly sharp. Poorly to moderately formed, moderately well finished; matte.

Asymmetrical profile suggests stylized duck form.
W 36. Stone/metal (hematite-goethite/limonite [?] lead) sphendonoid weight.
Inv. No. KW 2336 Museum Inv. No. 27-19-90
O 14 UL 1
L. 2.405; w. 1.503; overall h. 0.935; stone h. 0.908; hole diam. 0.551; mass 8.02 g (-).
Dark brownish red; speckles of iron oxidation products. Surface of lead plug covered with lead and some iron oxidation products. Complete, moderately preserved. Surface erosion and minute pitting over base, most of lower one-half of one side, and ends. Several small chips along base edge and on top at edge of one end. Eroded natural stone “grain” line extends from one end along most of one side and ends at large chip at opposite end’s edge. Surface of lead plug corroded and eroded to slightly below level of base surface, except for one small portion protruding beyond base surface.

Top view reveals curved sides and truncated ends. Side view shows fully rounded top, with straight ends angled outward to base. End view shape hemispherical with somewhat elongated sides. Flat base reaches over entire length, nearly all of width; edge sharp. Well formed and finished; matte to low polish. Polish marks on base inclined ca. 30 degrees from short axis, while on top they run across width in several directions, sometimes criss-crossing.

Notably off-center round hole in base contains oxidized remains of lead plug, some of which barely protrude beyond base surface.
Stone (limonite) sphendonoid weight.  

Museum Inv. No. 40-19-90  
N19 LR4

Inv. No. KW 2377

L. 2.411; w. 1.360; h. 1.076; mass 8.23 g.

Dark brownish red; patches and speckles of iron oxidation products. Complete, moderately well preserved. Some superficial and deeper surface erosion; small, dense patch of minute to small pits at mid-length on top, large patch on top near one end, some minute pitting on base. Several medium-size chips on top surface.

Top view shows both side curvatures rather irregular, one slightly fuller and smoother than the other; ends truncated, somewhat rounded. Side view shows top rather fully rounded, essentially straight ends angle somewhat inward to base. End view shape fully rounded, truncated circle. Base reaches over entire length, most of width, and is slightly convex over both axes; edge fairly sharp. Moderately formed, moderately well finished; matte to medium polish. Polish marks on base and sides are essentially parallel to long axis, those on top inclined ca. 30 degrees from long axis.
W 38. Stone (unidentified softish stone) domed weight. Museum Inv. No. None
Inv. No. KW 4100
Max. diam. 2.043; min. diam. 1.972; h. 1.291; mass 8.38 g.
Gray to black. Complete, excellently preserved. One minute scratch; a
short, shallow, curved crack on top surface is flaw in stone.
Circumference shape irregularly rounded. In cross section, top
unevenly rounded and merges with essentially vertical side surface by means
of a crude bevel; crude bevel also joins side surface and base. Base flat,
edge fairly sharp. Moderately formed, well finished; matte.
Inv. No. KW 3836
Max diam. 2.529; min. diam. 2.474; max. th. 0.564; min. th. 0.393; pres.
mass 8.72 g (-).
Black; some copper oxidation products. Incomplete, poorly preserved; one
small piece reattached. Significant erosion on part of top surface and most
of base; much of side, part of top, and most of base surface exfoliated.
Original circumference shape virtually a circle. Cross section shows
slightly convex top and vertical sides. Base flat, with fairly sharp edge. Well
formed, quality of finish indeterminate; matte.
Coin-like shape.
W 40. Stone/metal (ilmenite [?] / lead) sphendonoid weight.
Inv. No. KW 227

Museum Inv. No. 98-31-84
O15 LL4

L. 2.517; w. 1.307; overall h. 1.102; stone h. 1.064; max./min. hole diam. 0.535, 0.474; mass 9.64 g (-).

Dark gray to black; off-white lead oxidation products on and around lead plug. Complete, well preserved. Superficial surface erosion over most of weight. Minute and minor pitting at ends, over one side, and on base; one medium-size pit on side near one end. Approximately one-fourth of lead plug's edge chipped away.

Top view reveals that two diagonally opposed halves of the side curvatures straight for some length; ends truncated and slightly rounded. Side view shows top curvature similar to those of sides; straight ends angle slightly inward toward base and each joined to it with a short bevel. End view shape truncated circle with two faint flat spots. Flat base covers most of length and width; edge somewhat rounded. Well formed and finished; matte to medium polish.

Barely elliptical lead plug in base slightly off center and expanded somewhat from oxidation; about half its circumference protruded beyond the base surface before it was chipped away. Concave part of plug represents original surface.
W 41. Stone (hematite) loaf-shaped weight. Museum Inv. No. 24-5-87
Inv. No. KW 729 N15 UL 1
L. 1.822; w. 1.360; h. 1.197; dimple diam. 0.102; depth ca. 0.02; mass
10.28 g.

Dark brownish red with blue tinge. Complete, very well preserved. Some
superficial surface erosion on all surfaces; some minute pitting over top and
ends, one small pit on top at one end.

Top view shape essentially a rectangle but with slightly convex sides
and rounded corners. In side view, top faintly convex, each end convex and
linked to base by short, rounded bevel. End view shows a truncated ovoid.
Flat base over most of length and width; edge rounded. Moderately well
formed, very well finished; matte. Faint abrasion marks on one end inclined
about 30 degrees from vertical.
W 42. Stone (kaolin or argillite ?) loaf-shaped weight. Museum Inv. No. 21-5-87
Inv. No. KW 731
L. 2.098; w. 1.302; h. 1.131; pres. mass 7.22 g (-); cal. mass 10.29 g.
Off-white; appreciable iron oxidation products and some tan to dark brown stains. Incomplete, poorly preserved. Appreciable surface erosion and exfoliation; some small pits and thin crack over length of top and partly down both ends; approximately one-third of length missing.

Top view shows one side just faintly convex, the other gently so; extant end truncated and barely rounded, corners rounded. Side view exhibits gently rounded top and barely convex extant end. End view shape essentially a truncated circle with two flattened spots. Flat base extends over entire preserved length and most of width; edge somewhat rounded. Seems to have been moderately well formed and finished; matte.
W 43. Stone (hematite) domed weight.  
Inv. No. KW 787  
Museum Inv. No. 20-5-87  
M11 LL3  
Top l. 2.112; w. 1.683; base l. 1.596; w. 1.451; h. 1.120; mass 10.37 g.  
Light to dark brownish red. Complete, well preserved. Some surface erosion on base in "squiggle" pattern, and two small pits. Several small exfoliated areas on top surface; exfoliated and chipped area around ca. one-quarter of base edge.  
Circumference shape elliptical with straight length near one end. Longitudinal cross section exhibits uneven, flat top and convex side surface joined by sometimes faint, sometimes distinct, rounded bevel; similar bevel joins side surface to base. Lateral cross section similar. Base flat with fairly sharp edge. Moderately formed. Quality of finish indeterminate, as top and side surfaces are irregular, as if exfoliated in many small spots and then worn or polished smooth; medium polish.
W 44. Stone (ilmenite) irregular weight.  
Inv. No. KW 5739  
Museum Inv. No. None  
M16 LR1  
L. 1.926; w. 2.028; h. 1.284; mass 10.45 g.  
Dark brownish red, lighter shades in damaged areas. Complete, poorly preserved. Extensive surface erosion; small to large pits and chips here and there over entire surface.  
Shape in all views irregular. Largest flat surface worked, as indicated by fine abrasion or polish marks running parallel to its long axis over entire width and most of length. Poorly formed and finished; matte.
Inv. No. KW 3318 N18 UR3
L. 2.536; w. 1.387; h. 1.061; mass 10.47 g.
Dark brownish red; black stains over much of top probably oxidation products. Complete, well preserved. Some superficial surface erosion; several minute and small pits over top, sides, and on base at edge. Eroded line of stone “grain” extends most of base’s length near one edge.

Top view shows one side curvature somewhat fuller than the other, and ends truncated and parallel, but inclined to weight’s long axis. Side view reveals rounded top; slightly rounded ends are angled somewhat inward to base and joined to it by one short straight and one short convex bevel. End view shape a truncated circle with one small flat spot. Flat base reaches over nearly entire length and width; edge fairly sharp. Well formed and finished; matte to medium polish.
Stone/metal (ilmenite [?]/bronze) sphendonoid weight with loop at one end. Inv. No. KW 5143
Museum Inv. No. None
M16 UL2

L. 2.764; w. 1.228; h. 1.071; small hole diam. 0.138; large hole diam. 0.282; loop max. sectional dimensions 0.399 x 0.441; pres. mass 10.61 g (-). Darkest brownish red to black; gray mottling in areas of surface erosion. Incomplete, well preserved. Surface erosion around loop end and here and there; one medium-size chip at edge of larger hole and a large one at end opposite loop. Broken metal suspension loop displays a few small to medium-size pits. Small piece of loop missing at smaller hole.

Top view shows side curvatures approach bilateral symmetry, ends truncated. Side view shows nicely rounded top and essentially straight, vertical ends each joined to base with a faintly convex bevel. End view shape is a truncated circle. Flat base reaches over most of length and width; edge fairly sharp. Very well formed and finished; high polish.

Oblong loop at one end presumably passes through weight completely. Its sectional shape seems to be oblong to lentoid, with dimensions smallest at break and largest in central portion of its length. Plane of loop, currently in shape of a closed horseshoe and extending beyond nearer end of weight, is inclined toward base. Hole axis almost perpendicular to long axis of weight and inclined slightly to base. Hole appears to have been drilled completely through from one side with a tapered bit, as suggested by markedly differing diameters of entry and exit holes.
W 47. Stone (compact limestone) sphendonoid weight.
Inv. No. KW 462
Museum Inv. No. 52-24-86
N12 UL1

L. 2.859; w. 1.873; h. 1.294; mass 10.68 g.
Translucent reddish tan to off-white. Complete, well preserved. A few shallow pits on top surface.

Top view shows two fully rounded, somewhat irregular side curvatures and truncated, slightly rounded ends. Side view reveals gentle, but slightly angular top curvature; ends are straight, essentially vertical, and joined to base by one straight and one slightly convex bevel. End view shows faintly rounded top, and fully rounded sides with flats indicative of facets along weight’s length. Flat base extends over most of length and width, edge rounded. Moderately formed and finished; matte. Crude abrasion marks on all surfaces look more like results of forming, not polishing, though surfaces are smooth.
Inv. No. KW 803
L. 3.027; w. 1.430; h. 1.314; mass 10.75 g.
Dark yellowish green. Nearly complete, very well preserved. Minute
chips on top edge at one end and several around base edge; two short,
shallow, rather broad gouges at base edge on one side.
Top view reveals a quadrilateral with faintly rounded sides and more
rounded ends. Side view shows top curvature is an arc; both ends barely
convex. End view shape triangular, but truncated and quite rounded at
apex. Base reaches over entire length and width, slightly concave along
length, flat over width; edge fairly sharp. Well formed, very well finished;
low polish.
W 49. Stone (compact limestone) domed weight. Museum Inv. No. None
Inv. No. KW 5130 M16 URI
Top l. 2.282; w. 1.902; base l. 2.060; w. 1.653; h. 1.540; mass 10.89 g.
White tinged with lightest gray, some gray veins; iron oxidation products
primarily over one longitudinal half of the top and extending slightly onto
base. Complete, very well preserved. Small number of minute and small
pits, gouges, and scratches on all surfaces.

Circumference shape ovoid. Longitudinal cross-sectional shape a
truncated ovoid with small and faint facet on top near narrower end.
Lateral cross-sectional shape is an ovoid with its broader end truncated.
Base flat with sharp edge. Moderately well formed, well finished; medium
to high polish. Polish marks on base oriented ca. 45 degrees to axes.
W 50. Stone (hematite) sphenoid weight.

Museum Inv. No. 22-5-87

Inv. No. KW 921

M10 LL1

L. 2.789; w. 1.324; h. 1.274; mass 10.92 g.

Dark reddish brown with lighter patches; one patch of iron oxidation products. Incomplete, moderately preserved. Some superficial surface erosion; minute to medium-size pits over most of weight; medium-size chip at one end, large chip on one side near top.

Top view reveals side curvatures irregular and one end slightly truncated, the other nicely rounded except for chip at that end. Side view shows top curvature is faintly faceted, one end straight and angled inward toward base, the other roughly rounded, each joined to base with rounded bevel, one of which is somewhat convex. End view shows fully rounded, but multi-faceted, truncated circle. Flat base reaches over most of length and width, edge sharp. Moderately formed, moderately well finished; matte to low polish.
Stone (hematite) spheronoid weight.

Museum Inv. No. None
Inv. No. KW 4310
O20 UL3

L. 2.461; w. 1.323; h. 1.251; mass 11.09 g.

Brownish red of varying shades. Complete, well preserved. Some
superficial surface erosion around one end; two small pits and one small
chip at same end, and small area of minute pitting on opposite end.

Top view shows two gently curved sides, one somewhat angular; ends
truncated at noticeable angles and roughly parallel, one quite rounded. Side
view reveals rounded top; one end rounded and linked to base with a
slightly rounded bevel, the other slightly rounded and angled inward toward
base, joined to it by means of a short, convex bevel. End view shape
irregularly triangular with rounded sides and vertices. Base extends over
most of length and width, slightly convex over both axes; edge rounded.
Moderately formed, well finished; matte to low polish.
W 52. Stone (hematite) loaf-shaped weight. Museum Inv. No. None
Inv. No. KW 5738 N16 LL3
L. 3.523; w. 1.516; h. 1.277; mass 14.28 g.
Brownish red; extensive copper oxidation products with some iron
oxidation products and black staining. Incomplete, moderately preserved.
Entire surface eroded; several small pits, one medium-size one on base.

Top view shows long, gently curving sides, ends truncated and
somewhat rounded. Side view reveals top curvature is also a long, gentle
curve; one end is convex, the other straight and essentially vertical. End
view shows irregularly rounded truncated circle. Flat base over nearly
entire length, most of width, edge rounded. Moderately well formed,
moderately finished; matte.
W 53. Metal (bronze) loaf-shaped weight. Museum Inv. No. 40-7-95
Inv. No. KW 3634 O17 LL4
L. 3.454; max. w. 1.447; min. w. 1.242; h. 0.595; mass 14.36 g. + 2.42 g.
(bits) = 16.78 g.
Brownish red; some exfoliated surfaces covered in copper oxidation products, and red and tan stains or discolorations here and there.
Incomplete, poorly preserved; some exfoliated pieces reattached. Original surfaces at both ends eroded and exfoliated, with perhaps 90 percent of entire surface thickly exfoliated; some recrystallized copper adheres to original surfaces of ends.
Top view shape a quadrilateral with slightly rounded sides, ends, and corners; portions of longer sides faintly concave. Side view shows nearly flat top and straight, short, virtually vertical ends. The end view reveals gently rounded top and straight, short, essentially vertical sides. Flat base over entire length and width; edge rounded to fairly sharp. Moderately well formed, quality of finish indeterminate; matte.
W 54. Stone (ilmenite) domed weight. Museum Inv. No. 18-7-95
Inv. No. KW 3834 M15 LL4
Max. top diam. 2.124; min. diam. 2.003; max. base diam. 1.568; min. diam.
1.513; h. 1.643; mass 18.70 g.
Dark greenish gray; larger pits and chips reddish brown. Complete,
moderately well preserved. Minute pitting over top and side surfaces,
three large patches of small pits, scattered medium-size pits, and two large
pits on side surface near base and on one base edge.
Circumference shape faintly oblong and irregular. Both cross sections
show slightly uneven, rounded top that merges smoothly into convex side
surfaces. Base flat with fairly sharp edge. Moderately formed, well
finished; matte to medium polish.
W 55. Stone (hematite) loaf-shaped weight. Museum Inv. No. 64-24-86
Inv. No. KW 493 K14 LR1
L. 2.982; w. 1.448; h. 1.460; mass 18.78 g.
Dark brownish red with blue tinge. Complete, moderately well preserved.
Minute to medium-size pits over entire surface, a large one on one side;
small chips at both ends and a large one at one end on base edge; one short,
shallow gouge on top surface.
Top view shape oblong with one straight side and one uneven, slightly
curved side; one end is truncated, somewhat rounded, the other more so but
uneven. Side view shows top unevenly rounded, each end angled inward
toward base and linked to it by a slightly rounded bevel. End view shows an
irregular quadrilateral with a short, slightly inclined, flattened top, one
faintly convex side and one rounded one, each joined to base with a short,
somewhat rounded bevel, and rounded corners. Base over most of length
and width uneven and somewhat convex over both axes; edge rounded.
Poorly formed and finished; matte.
Stone (hematite) sphendonoid weight.

Museum Inv. No. 17-5-90
Inv. No. KW 1812
M15 LR1

L. 3.585; w. 1.606; h. 1.246; mass 18.82 g.
Brownish red with blue tinge and black mottling. Complete, well preserved. Some superficial surface erosion, especially on side surfaces near base; minute pitting here and there on one side and on ends. Two medium-size chipped or pitted spots on base, one small chip on base bevel at one end.

Top view shows one side curvature barely angular and fuller than other, and truncated ends essentially parallel and slightly inclined to weight's long axis. Side view reveals top curvature slightly angular, each end irregularly convex and linked to base with faintly convex bevel. End view shape essentially truncated circle faintly flattened on top. Flat base, somewhat displaced toward one end, covers most of length and width; edge rounded to fairly sharp. Moderately well formed, very well finished; matte. Faint polish marks on most of base slightly inclined to short axis.
W 57. Stone (chalky limestone) domed weight. Museum Inv. No. 16-7-92
    Inv. No. KW 2762  O14 LL3
    Max. top diam. 2.240; min. diam. 2.211; max base. diam. 1.783; min. diam. 1.614; h. 1.670; pres. mass 18.70 g (-); cal. mass 18.83 g.
    Original surfaces very light gray, eroded areas creamy white; a thin, brownish-red variegation extends along one edge of base and up onto side surface. Complete, well preserved. Most of surface shows superficial erosion or thin exfoliation, with original surface remaining only in one patch of top surface near base, aside from small scattered spots; one large chip on base edge.
    Circumference shape virtually a circle. Cross-sectional shape a truncated circle. Base flat except for small depression; edge fairly sharp. Well formed, quality of finish indeterminate; matte.
W 58. Stone (hematite) sphendonoid weight.  
Inv. No. KW 4546  
L. 3.197; w. 1.572; h. 1.269; mass 18.83 g.  
Brownish red with black mottling. Complete, well preserved. Several minute pits on top surface and one end; small chips around base edge, one large chip on one side, another on opposite side at one end.  
Top view shows one side curvature more angular than other; ends truncated, somewhat rounded. Side view exhibits rounded top and slightly convex ends barely angled outward. End view shape essentially truncated circle with one faint, flattened spot on one side near base. Flat base reaches over most of length and width; edge fairly sharp. Well formed and finished; matte.
Inv. No. KW 4272 M16 UR4
Max. top diam. 2.030; min. diam. 1.963; max. base diam. 1.443; min. diam. 1.234; h. 1.804; mass 19.62 g.
Brownish red with black and white inclusions, especially exposed in one rough patch on side surface; moderately large area on side near top stained pale green to virtually black with copper oxidation products partly overlain by faint orange of iron oxidation products. Complete, well preserved. Some superficial surface erosion, minute pitting, and gouging on top and side surfaces.
Circumference shape irregularly rounded with vestiges of five or six facets. Cross-sectional shape essentially an inverted truncated cone, planes of top and base not parallel; faintly convex top joined to faintly convex side surface by crude, rounded bevel. Base essentially flat with rounded edge. Poorly formed, well finished; matte.
W 60. Metal (lead) discoid weight. Museum Inv. No. 129-5-87
Inv. No. KW 788 M11 LL3
Max. diam. 2.155; min. diam. 1.944; max. th. 0.892; min. th. 0.772; mass 19.88 g (-).

Grayish brown through tan to white; exposed lead typical gray. Complete, well preserved. Thin coating of compact corrosion products preserves original surface details. Some cracks in coating on side surface and on one flat surface. One medium-size chip in corrosion layer exposes bare lead on same surface at edge; fewer and finer cracks on opposite surface.

Circumference shape irregularly rounded with four faintly straight lengths that constitute more than half of circumference. Cross section shows top and bottom surfaces slightly concave due to raised edges around most of both perimeters; side surface is convex or essentially straight, vertical, and irregular. Moderately formed; quality of finish indeterminate; matte.

Surface with medium-size chip in corrosion layer exhibits six faint impressions of roughly similar size confined to one-half of surface, and located nearer edge than center of surface; four are triangular, one a quadrilateral, the last rather tear-drop shaped. Three triangles grouped together and somewhat antithetical, fourth lies nearby and adjacent to tear drop, with the quadrilateral near opposite edge. Very faint curved ridge roughly bisects latter, almost as if it consists of two triangles with common curved hypotenuse. The opposite surface displays four similar impressions, also nearer edge than center, and confined to one-half of surface. One is essentially two contiguous sides of a square or rectangle, smallest is triangular and lies immediately adjacent to an irregularly rounded form, and fourth is tear-drop shaped.

Most of these impressions appear to be “dents” made by flat surfaces of various hard objects. Tear-drop shaped one and the rounded one, both located on surface with just four marks, however, appear to have been made by objects with rounded surfaces. No patterns of placement, orientation, or size evident; their significance seems indeterminate.
Stone (hematite) loaf-shaped weight. Museum Inv. No. 22-24-86
Inv. No. KW 323 L11 UR4
L. 3.184; w. 1.523; h. 1.464; mass 22.02 g.
Dark brownish red. Complete, very well preserved. Minute pitting over entire surface but especially at one end, with several medium-size ones confined to one-half of weight's length.

Top view shows two long, uneven, faintly rounded sides; narrower end truncated and rounded, the wider end truncated and barely rounded with about one-half of surface beveled as well. Side view reveals rounded top; truncated/beveled end slightly convex, other angles inward somewhat to meet faintly convex bevel joining it to base. End view shows top and one side unevenly rounded, and one vertical side (side facet) joined to base with bevel. Flat base over nearly all of length and width; edge rounded.
Moderately formed, moderately well finished; matte to medium polish. Polish or shaping marks on top essentially parallel to long axis of weight or slightly inclined to it; those on truncated/beveled end are perpendicular to base.
W 62. Metal (bronze) sphendonoid weight. Museum Inv. No. 24-5-90
Inv. No. KW 1771 M12 UR2
L. 3.767; w. 1.540; h. 1.267; hole l. 0.565; w. 0.265; depth 0.55; interior l.
ca. 1.0; w. ca. 0.75; pres. mass 18.69 g (-); est. mass 25.56 g.
Various shades of brownish red; copper oxidation products in damaged
areas. Incomplete, poorly preserved; some exfoliated pieces reattached.
Approximately two-thirds of surface significantly eroded, corroded, and
exfoliated through several thin layers, with remaining surface area thickly
exfoliated down to smooth sub-surface that exhibits some superficial surface
erosion. Abundant recrystallized copper around inner and outer edge of
hole in base and within it.
Top view shows both side curvatures are angular, one more than the
other; ends truncated. Side view reveals notably angular top curvature, one
end straight and vertical, the other somewhat rounded and angled inward to
base. End view shape essentially a truncated circle. Flat base reaches over
virtually entire length and most of width; edge fairly sharp. Well formed,
quality of finish indeterminate; matte.
A now roughly rectangular hole for lead plug in base, obscured by
recrystallized copper deposits, slightly off center. Interior dimensions
notably greater than those at base surface.
Stone (hematite) sphendonoid weight.

Inv. No. KW 4944
L. 3.948; w. 1.738; h. 1.516; pres. mass 24.92 g. + 0.33 g. (bits) = 25.25 g
(-); cal. mass 25.96 g.
Brownish red with blue tinge. Incomplete, poorly preserved; one large
piece reattached. Surface erosion on lower half of weight; medium-size pits
dense over most of lower half and all of preserved base surface. About one-
third of weight broken away diagonally at one time, of which a large piece
has been reattached, such that perhaps one-sixth of the weight still missing.

Top view reveals one side curvature fuller than other, extant end
truncated and somewhat rounded. Side view shows top gently rounded;
preserved end somewhat rounded and joined to base with slightly convex
bevel. End view shape a truncated circle. Base covers most of length and
width, degree of flatness and sharpness of edge indeterminate. Well formed
and finished; matte.
W 64. Stone (chalky limestone) domed weight. Museum Inv. No. 71-24-86
Inv. No. KW 521 M11 LR3
Max. diam. 2.650; min. diam. 2.555; h. 1.835; mass 27.28 g.
Off-white with tannish tinge; black stains and iron oxidation products over
one patch of top, ca. one-third of which is covered with copper oxidation
products. Complete, very well preserved. Some superficial surface
erosion; one medium-size chip on base at edge.
Circumference shape irregularly ovoid. Longitudinal cross section
shows asymmetrical dome rounding sharply into base. Lateral cross-
sectional shape resembles truncated cone with smoothly rounded top and
convex sides rounding sharply into base. Base barely concave; edge
rounded. Moderately formed, well finished; matte, somewhat chalky.
W 65. Stone (hematite) sphendonoid weight. Museum Inv. No. 35-5-87
Inv. No. KW 794  M15 UR3
L. 4.237; w. 1.786; h. 1.482; mass 27.40 g.
Dark brownish red with blue tinge. Complete, moderately preserved.
Entire surface densely covered with minute to medium-size pits. Several
scattered small chips, one large one on underside obscures one bevel
between end and base; nearly one-half of base surface chipped away.
Top view reveals one side curvature fuller than other; ends truncated,
one rounded. Side view shows top rounded, faintly angular, with essentially
straight ends, one vertical and one angled slightly inward toward base. The
preserved bevel linking one end to base is faintly convex. End view shape a
truncated circle somewhat flattened on top and one side. Flat base extends
over most of length and width; edge somewhat sharp to rounded.
Moderately well formed, well finished; medium polish.
W 66. Stone (chalky limestone) domed weight. Museum Inv. No. None Inv. No. KW 4369 M15 LL4

Max. diam. 2.774; min. diam. 2.703; h. 1.733; mass 27.90 g.
Off-white with darker speckles due to pitting; orangish yellow stain at two points on side surface at base and extending across it. Complete, very well preserved. Superficial surface erosion and fairly uniform minute pitting over top surface; one medium-size chip on base at edge.

Circumference shape nearly a circle. Cross-sectional shape an ovoid truncated at about mid-length, thus essentially a dome. Base slightly concave with sharp edge. Moderately well formed and finished; matte, somewhat chalky.
W 67. Stone (chalky limestone) domed weight.
Inv. No. KW 3972
Museum Inv. No. 26-7-95
O18 LL4
Max. diam. 2.573; min. diam. 2.493; h. 1.916; mass 27.93 g.
White to off-white; copper oxidation products here and there on top and side surfaces. Complete, well preserved. Minute abrasions of various lengths and orientations here and there over top and side surfaces.
Circumference shape irregularly round. Cross-sectional shape shows irregularly rounded top with one facet extending across top edge onto irregular side surface, which is gently convex to vertical. Base flat with rounded edge. Moderately formed, quality of finish indeterminate; matte, chalky.
W 68. Metal (lead) domed weight. Museum Inv. No. None
Inv. No. KW 1168 M15 UR3
Max. diam. 1.890; min. diam. 1.693; h. 1.619; mass 27.98 g (-).
Dark to light gray, and cream where exfoliated; some copper oxidation
products. Complete, moderately preserved. Thin coating of compact
corrosion products preserves original surface details, with some cracking
of this coating on top and side surfaces; several small exfoliated spots.
Small, elongated cavity in approximate center of top and roughly triangular
one slightly smaller in center of base.

Circumference shape irregularly ovoid. Longitudinal cross-sectional
shape a short barrel with slightly pointed top. Lateral cross-sectional shape
resembles truncated circle with flattened length perpendicular to plane of
base. Base somewhat uneven; edge fairly sharp. Moderately formed,
quality of finish indeterminate; matte.
W 69. Stone (hematite) sphendonoid weight. Museum Inv. No. 12-1-94 Inv. No. KW 3196 N16 UL3
L. 3.594; w. 1.867; h. 1.717; mass 28.13 g.
Dark brownish red with blue tinge; large black stain and some iron oxidation products. Complete, well preserved. Some superficial surface erosion. Many small to medium-size pits over all surfaces; a few small chips at ends and on top, and one medium-size one on top.
Top view exhibits one irregular side curvature, one angular one, and rounded, truncated ends. Side view shows top curvature angular, one end rounded, and one nearly straight and angled slightly outward, each joined to base by a slightly convex bevel. End view shape essentially a truncated circle with one somewhat flattened side. Flat base reaches over most of length and width; edge sharp. Moderately formed, well finished; low to medium polish. Some polish marks near base along one side at one end.
W 70. Metal (bronze) sphendonoid weight. Museum Inv. No. 14-1-94
Inv. No. KW 3238 M16 UR4
L. 3.531; w. 1.625; h. 1.186; hole l. 0.938; w. 0.521; depth 0.428; pres.
mass 15.76 g (-); est. mass 28.30 g.
Black; damaged areas display copper oxidation products. Incomplete,
moderately preserved. Thin exfoliations scattered over top surface,
deeper exfoliations around ends and over most of base.

Top view reveals two fully rounded sides, with slight concavity on one
side near the more pointed and slender of two pointed ends. Side view
shows somewhat irregular top curvature; one end pointed, the other straight
and essentially vertical, each joined to base with a faintly convex bevel. End
view shape resembles a truncated circle with harder curvatures at base and
slightly flattened top and one side. Flat base covers most of length and
width; edge somewhat sharp to rounded. Moderately formed, quality of
finish indeterminate; matte to medium polish.

Rectangular hole in base for lead plug slightly off center. Its interior
length and width are greater than at base surface, the length markedly so.
Bottom of hole comprises three rough, shallow depressions.
W 71. Stone (hematite) sphendonoid weight. Museum Inv. No. None Inv. No. KW 5751 N17 UR2
L. 3.616; w. 1.937; h. 1.624; mass 28.75 g.
Dark brownish red with blue tinge and some black mottling; some iron oxidation products. Complete, excellently preserved. Some minute pitting on base near edge extends partly onto one side.
Top view shows two full, angular side curvatures, one fuller and more angular than the other; ends truncated, essentially parallel, and slightly inclined to long axis of weight. Side view reveals rounded, somewhat angular top curvature and straight ends that angle barely inward to base, each adjoined to it with a barely convex bevel. End view shape a truncated circle with faint flat spot. Flat base covers most of length and width; edge fairly sharp. Well to very well formed, very well to excellently finished; matte to low polish.
W 72. Stone (hematite) trapezoidal weight. Museum Inv. No. None
Inv. No. Lot 2801
K 14
L. 3.162; w. 2.617; h. 1.634; pres. mass 28.86 g (-).
Dark brown. Nearly complete, moderately to well preserved. Some
superficial surface erosion; on top is small group of small to medium pits,
and one large pit; several chipped areas around side surface and on base.

Top view shape is roughly trapezoidal with one vertex on wider side
chipped away. Side view shows inclined, slightly irregular top; one end
irregularly rounded, the other flattened. Wider end view shows flattened
top and higher side rounded, opposite side flatter but chipped away at
corner. Base over entire length and width is flattened but very irregular.
Quality of form poor or indeterminate, moderately finished; matte to low
polish.

Some chipped areas on side and base surfaces may be shipwreck
damage, but seem more likely to have been damaged during use and
subsequently worn from continued use.
W 73. Stone (hematite) discoid weight.  
Museum Inv. No. 23-24-86  
Inv. No. KW 325  
L11 UR4  
Max diam. 2.785; min. diam. 2.585; th. 1.232; first hole max. diam. 0.370;  
min. diam. 0.362; second hole max. diam. 0.415; min. diam. 0.383; mass  
28.94 g.  
Dark reddish brown. Complete, well preserved. Some minute pitting and  
several medium-size pits on top and side surfaces; minor chipping  
avoided hole edges and two small chips on base at edge.  
Lentoid disc pierced through diameter. Circumference shape  
irregularly round with vestiges of four facets, and two straight, non-parallel  
lengths at hole openings. Longitudinal cross section (along hole axis)  
exhibits slightly uneven, sloping top with slightly inclined facet extending  
from thickest point to one end, and shorter, more steeply inclined facet  
reaching from top to opposite end; ends straight and essentially vertical.  
Lateral cross section also shows slightly uneven and sloping top, convex  
sides, and short bevels with rounded edges that join sides with top and base.  
Base barely convex with mostly rounded edge. Moderately formed,  
moderately well finished; medium to high polish.  
Round to faintly oblong tapered holes drilled from approximate center  
of opposing ends meet near center of piece. No evident wear around holes,  
only minor chipping around edges, probably associated with drilling process.
Stone (hematite) sphendonoid weight.  
Museum Inv. No. 24-7-95  
Inv. No. KW 3765  
O17 LL2

L. 3.592; w. 1.621; h. 1.679; mass 29.11 g.

Dark brownish red with blue tinge; some spots of iron oxidation products.
Complete, moderately well preserved. Some superficial surface erosion; minute to medium-size pits on all surfaces. Several minute to small chips on each end, one large one on underside of one end.

Top view reveals one full side curvature, the other less full and somewhat angular, and truncated ends, one barely rounded. Side view shows top curvature slightly irregular and angular, each straight end essentially vertical and joined to base with slightly convex bevel. End view shape a truncated circle with faint flat spots to both sides of top. Base over most of length and width barely convex along both axes, edge rounded. Moderately well formed, well finished; low polish.
W 75. Metal (bronze) sphendonoid weight. Museum Inv. No. 63-24-86
Inv. No. KW 492  K14 LR1
L. 3.576; w. 1.675; h. 1.349; pres. mass 22.41 g (-).
Tip of one end chipped away; thin cracks over top, side, and base.

Top view shows two angular side curvatures, fairly sharp tip on
preserved end. Side view shows top curvature uneven and angular, with
small concavity to one side of angle's "apex." Intact end is a rounded point
joined to base, as was the missing end, by means of slightly convex bevel.
End view shape is basically a truncated circle with several flat spots. Barely
convex base over both axes extends over most of length and width, edge
rounded to moderately sharp. Moderately well formed, very well finished;
high polish. On top and sides are long, coarse, somewhat irregular tool or
finishing marks either parallel or slightly inclined to weight's long axis.

Tool and/or finishing marks along weight's length not continuous from
end to end, but extend roughly from side and top "apices" toward each end,
as if tool that was drawn along length started or stopped at approximately
mid-weight, though along one-half of one side the marks perpendicular to
base. Marks on base run perpendicular to long axis and quite fine, perhaps
result of polishing, whereas others seem more like tool marks left in wax or
on mold. Small concavity on top surface corresponds to dimple with
somewhat rough surface. Perhaps it is a flaw of some type or vent hole.
W 76. Stone (hematite) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 4438
N17 UR3
L. 4.560; w. 1.881; h. 1.723; mass 41.63 g.
Light orangish red; black staining over much of weight. Complete, well
preserved. Few small chips on base edge and at both ends, several
medium-size ones at one end and one on base edge; areas of thin
exfoliation on top, on one end, and on base near one end.

Top view shows side curvatures long, relatively flat and irregular, one
barely angular; ends truncated, one slightly rounded. Side view reveals top
curvature also long and somewhat flat, while each straight end angles
slightly inward toward base and joined to it with slightly convex bevel. End
view shape multi-faceted, with all edges rounded. Flat base extends over
nearly all of length and most of width; edge slightly rounded. Moderately
formed, well finished; matte to low polish.
W 77. Metal (bronze) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 4214
L. 3.810; w. 1.717; h. 1.496; mass 42.21 g.
Dark gray to black. Incomplete, moderately preserved. Entire surface
uniformly eroded and pitted; both ends chipped, one completely lost; several
small exfoliated spots.

Top view reveals virtual bilateral symmetry of side curvatures, ends not
preserved. Side view shows rounded, nearly angular top; each end joined to
base by barely convex bevel. End view shape fully, but somewhat
irregularly, rounded. Flat base reaches over most of length and width; edge
rounded. Very well formed, well finished; low polish.
Metal (bronze) sphendonoid weight.  
Museum Inv. No. 74-24-86  
Inv. No. KW 564  
M11 UL2
L. 3.295; w. 1.993; h. 1.582; max./min. hole diam. 0.629, 0.585; depth 0.320; pres. mass 37.83 g (-); est. mass 42.41 g.
Black; copper oxidation products and some brownish red patches.
Incomplete, moderately preserved. Surface erosion over entire weight; perhaps one-third of original surface exfoliated.
Top view shows both side curvatures angular and one slightly fuller; ends are somewhat blunt. Side view shows top fully rounded and angular while both ends rounded, one joined to base by a short, barely convex bevel. End view shape essentially a truncated circle with one side displaying small flat near top and small bulge near base edge. Flat base covers most of length and width; edge rounded. Moderately formed, well finished; matte.
Barely off-center, irregularly circular hole in base for lead plug, with sectional shape that resembles a sugar loaf with rounded top.
Metal (lead) domed weight. Inv. No. KW 487
Museum Inv. No. 101-24-86
K13 LR2

Max. diam. 2.418; min. diam. 2.299; h. 1.380; mass 42.62 g (-).

Shades of gray and tan; white, chalky, lead oxidation products on exfoliated surfaces. Complete, moderately preserved. A few small patches and spots of thin coating of compact corrosion products preserves original surface details, while remainder of original surface exfoliated; one medium-size chip on base at edge.

Circumference shape virtually a circle. Cross section shows rounded top smoothly rounding into straight, essentially vertical side surface. Base notably concave with fairly sharp edge. Well formed, quality of finish indeterminate; matte.
W 80. Metal (bronze) sphendonoid weight. Museum Inv. No. 13-1-94
Inv. No. KW 3047 N18 UR3
L. 4.059; w. 1.684; h. 1.545; pres. mass 43.16 g (-); est. mass 43.66 g.
Darkest gray to black. Nearly complete, very well preserved. Some
superficial surface erosion, especially on lower sides near base; a few
minute chips on tip of one end, one small chip on opposite end.

Top view shows one side curvature slightly fuller than other, ends taper
to blunt points. Side view shows top curvature matches that of slightly
fuller side curvature of the top view; each straight end angles inward slightly
and joined to base with somewhat convex bevel. End view shape a
truncated circle. Flat base covers about one-half of length and most of
width; edge rounded. Very well formed and finished; matte to low polish.
W 81. Stone (hematite) prismatic weight. Museum Inv. No. 34-5-87
Inv. No. KW 967
N15 UL3
L. 3.637; w. 2.636; h. 2.207; mass 45.62 g.
Brownish red; some black staining and iron oxidation products. Complete, moderately preserved. Superficial surface erosion over most of weight; minute to small pits over entire surface and especially dense on ends. Several small to medium-size chips and six large ones; some exfoliation on one side surface; one end appears to have been broken and reworked in antiquity.

Side view shapes essentially rhomboids but with rather rounded ends and corners, though some corners are bevelled. End view triangular with one truncated vertices. Moderately formed and finished; matte to low polish.
W 82. Stone (hematite) sphenodontoid weight. Museum Inv. No. 20-7-95
Inv. No. KW 3467 O19 LL1
L. 4.392; w. 2.271; h. 1.859; mass 45.65 g.
Brownish red with hint of blue tinge; some black staining. Complete, well
preserved. Some surface erosion; minute to small pits over much of sides
and base, especially at ends and along base edge, and several medium-size
pits and small chips here and there.

Top view shows one side curvature slightly fuller than other; ends
truncated. Side view shows rounded top and essentially straight, vertical
ends, each linked to base with barely convex bevel. End view shape a
truncated circle with one small flattened spot.Flat base extends over most
of length and width; edge fairly sharp. Well formed, very well finished;
mattte to low polish.
W 83. Stone (hematite) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 4125 N16 UL 1
L. 4.170; w. 2.332; h. 1.914; mass 45.82 g.
Brownish red with blue tinge. Complete, very well preserved. Some
superficial surface erosion, especially in densely pitted areas. Dense, minute
pitting along about one-half of one side and along base edge of same side,
less dense but appreciable over remainder of surfaces; several small pits on
top, one side, and one end.

Top view shows full side curvatures and truncated ends. Side view
shows top also fully rounded and each straight, essentially vertical end
adjoins base by means of faintly convex bevel. End view shape a truncated
circle. Flat base covers most of length and width; edge fairly sharp. Very
well formed and finished; matte.
W 84. Stone (hematite) sphendonoid weight. Museum Inv. No. 25-7-95
Inv. No. KW 3839 O17 UL1
L. 4.305; w. 2.238; h. 1.951; mass 45.84 g.
Brownish red with blue tinge; small spots of iron oxidation products over most of surface. Complete, moderately preserved. Some surface erosion; minute to medium-size pitting extensive, with one large pit on base.
Top view shows one side curvature slightly irregular and a bit fuller than other; both ends rounded, one slightly angular. Side view reveals top curvature somewhat angular, ends rounded. End view shape irregularly rounded with one flattened length near top, and each side joined to base with crude, convex bevel. Base moderately displaced laterally, covers most of length and width, and slightly convex over both axes; edge rounded. Moderately formed, well finished; matte to low polish.
W 85. Stone (diorite) sphendonoid weight. Museum Inv. No. 26-24-86
Inv. No. KW 336 K14 LR3
L. 5.062; w. 2.725; h. 2.132; mass 46.24 g.
Greenish gray with blackish-gray inclusions and speckles; iron oxidation
products over much of surface. Complete, well preserved. Superficial
surface erosion over entire weight; top and sides covered with minute to
small pits, with several medium-size ones here and there.
Top view reveals one side curvature slightly uneven, the other a bit
fuller; ends are truncated and parallel but not quite perpendicular to
weight's long axis. Side view shows top rounded and each straight,
essentially vertical end joined to base with a faintly convex bevel. End view
shape a truncated circle. Flat base covers most of length and width; edge
sharp. Well formed and finished; matte.
W 86. Stone (hematite) sphendonoid weight. Museum Inv. No. 38-24-86
Inv. No. KW 377 L14 UL1
L. 4.607; w. 2.152; h. 1.943; pres. mass 46.38 g (-); cal. mass 46.61 g.
Brownish red with blue tinge. Complete, poorly preserved. Entire surface
eroded and extensively pitted and chipped; several large chips.
Top view reveals one side a notably angular curve, ends rounded with
one slightly blunt. Side view shows top a somewhat angular curve, ends
slightly rounded. End view shape originally a truncated circle. Flat base
over most of length and width, convex over both axes; edge rounded.
Moderately formed, moderately well finished; matte.
Stone (diorite [?]) domed weight. Museum Inv. No. None
Inv. No. KW 4547 N18 UR4
L. 3.516; w. 3.168; l. 2.463; w. 2.248; h. 2.729; mass 46.51 g.
Greenish gray with dark gray, black, and white inclusions. Complete, very
well preserved. Small to medium pits and small chips on all surfaces, all but
the largest nearly invisible due to homogeneity of stone.
Circumference shape irregularly elliptical with one bulbous long side.
Longitudinal cross-sectional shape with the most symmetry an ovoid
truncated parallel to its long axis. Lateral cross-sectional shape with the
most symmetry a truncated irregular circle. Base flat, edge fairly sharp.
Moderately formed and finished; matte.
W 88. Stone (hematite/ilmenite [?]) domed weight. Museum Inv. No. None
Inv. No. KW 4368 M15 LR3
Max. top diam. 2.664; min. diam. 2.581; max. base diam. 2.063; min. diam. 1.936; h. 2.361; mass 46.79 g.

Dark brownish red with some lighter patches; iron oxidation products over much of surface. Complete, very well preserved. Minute pitting here and there over top and base, two small pits on side near base.

Circumference shape an irregular circle. Cross-sectional shape an inverted ovoid truncated at its narrow end. Base slightly uneven with sharp edge. Well formed and finished; matte to low polish.
W 89. Stone (ilmenite) sphendonoid weight. Museum Inv. No. 23-7-95
Inv. No. KW 3801 M15 LR3
L. 4.320; w. 2.137; h. 1.882; mass 47.02 g.
Dark brownish red with blue tinge; largely covered with deep gray-green and some black staining. Complete, moderately preserved. Appreciable minute through small pitting and chipping over all surfaces except ends.

Top view shows one side curvature barely fuller than other and somewhat uneven, ends truncated. Side view shows top curvature also uneven; both ends are rounded, one more than the other, each joined to base with barely convex bevel. End view a truncated circle, but with many irregularities and flat spots. Flat base reaches over most of length and width; edge rounded. Moderately formed, well finished; low polish.
Stone (limonite/goethite) sphenonoid weight. Museum Inv. No. 32-5-87
Inv. No. KW 775
M11 LL4
L. 4.198; w. 2.473; h. 2.039; pres. mass 47.31 g (-); cal. mass 47.85 g.
Shades of tan to brown with black mottling; some iron oxidation products.
Complete, well preserved. Some superficial surface erosion in pitted areas; minute and some small pits over portions of all surfaces; large chips on both ends.
Top view shows both side curvatures uneven, one faintly faceted, and ends appear to have been rounded. Side view shows gentle top curvature, ends again appearing to have been rounded. End view reveals flat, sloping top and faintly faceted sides. Base extends over most of length and width, flat over long axis but slightly convex over short axis; edge rounded.
Moderately formed and finished; medium polish. Fine polish marks run in various directions, mostly along length.
W 91. Stone (hematite) sphenondoid weight. Museum Inv. No. None
Inv. No. KW 4964 M15 LL3
L. 5.946; w. 2.313; h. 2.0759; max./min. hole diam. (for both) 0.43, 0.39;
mass 73.89 g.
Dark brownish red with blue tinge, some black mottling. Complete,
moderately well preserved. Surface erosion in some damaged areas; minute
to small pits here and there; several small to medium-size chips. One thin
crack runs along most of length on top, while a somewhat larger one
obliquely encircles end pieced by hole, and largest crack similarly encircles
most of opposite end.

Top view reveals gentle side curvatures that approach bilateral
symmetry and rounded ends, one more blunt and wider than other. Side
view shows top gently rounded, and rounded ends, one joined to base by
faintly convex bevel. End view shape essentially a truncated circle with
small flat on top and sharper curve into base on one side. Flat base reaches
over most of length and width; edge rounded. Well formed and finished;
matte to low polish.

A barely oblong hole tapering toward center from both sides pierces
width near smaller end, its axis essentially perpendicular to weight's long
axis and parallel to base. A large wear area at one end of hole is ca. 0.65
cm. long and tapers in width from ca. 0.5 cm. to ca. 0.3 cm. toward nearer
end of weight and parallel to its long axis. The opposing end of hole
exhibits much smaller wear marks opposite one another, on axis inclined ca.
45 degrees toward top at weight's nearer end. Of these two, largest and
deepest is one nearer the base.
Metal (bronze) sphendonoïd weight. Museum Inv. No. 26-5-87

Inv. No. KW 874 N15 UL3
L. 4.720; w. 2.217; h. 2.018; pres. mass 76.04 g (-); est. mass 82.09 g.
Black; copper oxidation products where exfoliated, one yellowish green
stain. Incomplete, poorly preserved. Minute pits on edge of one end and a
medium-size one on base. Fully half of length on all but part of one side
densely pitted, as if repeatedly struck with blunt points of differing sizes,
with some areas appearing almost melted under low (8X) magnification.
Large patch on one side exfoliated; end on pitted half of weight so
severely pitted and chipped as to be incomplete.

Top view shows both side curvatures angular, and preserved end
truncated. Side view reveals that top curvature angular with the barest
concavity near preserved end, which is straight, essentially vertical, and
joined to base with slightly convex bevel. End view shape apparently
originally a truncated circle except for notable concavity on one side near
base. Base extends over less than one-half of length, more than half of
width, faintly convex over both axes; edge rounded. Well formed and
finished; matte to medium polish.
W 93. Metal (lead) domed weight. Museum Inv. No. 19-5-87
Inv. No. KW 1171 L15 LL3
Max. diam. 3.101; min. diam. 2.960; h. 1.637; mass 85.49 g (-).
Shades of gray and tan; green copper oxidation products over most of top
surface. Complete, moderately preserved. Thin coating of compact
corrosion products that normally preserves original surface details largely
exfoliated; one medium-size chip on base at edge.

Circumference shape virtually a circle, except about one-quarter of
circumference irregular. Side view shows truncated ovoid. Base flat with
sharp edge. Well formed, quality of finish indeterminate; matte.
W 94. Stone/metal (hematite/lead) sphendonoid weight. Museum Inv. No. 9-1-94 Inv. No. KW 3232 M16 UR4 L. 5.110; w. 2.780; overall h. 2.431; h. of stone 2.372; max./min. hole diam. 0.904, 0.841; mass 87.12 g (-). Dark brownish red with blue tinge, though most of base and underside lighter. Complete except for lead plug, well preserved. Superficial surface erosion and some minute to small pitting over most of surface; several minute chips around hole in base and one small one at one end. Surface of lead plug corroded, with a small hole into interior and over half of surface eroded to slightly below level of base.

Top view reveals both side curvatures slightly irregular and ends truncated. Side view shows curved top and straight, essentially vertical ends each joined to base by faintly convex bevel. End view shape a truncated circle with faint flat spots to either side of top and vestigial bevel adjoining base on one side. Flat base reaches over most of length and width; edge rounded. Well formed, very well finished; matte.

Round hole virtually in center of base contains oxidized remnants of lead plug, some of which barely protrude from base surface.
W 95. Stone (marl [?]) domed weight. Museum Inv. No. None
Inv. No. KW 3978 O18 LL2
Max. diam. 3.850; min. diam. 3.614; h. 3.120; mass 90.08 g.
Light tannish gray with off-white spots where damaged; copper oxidation
products over side surface and some of base. Complete, moderately
preserved. Significant superficial surface erosion; many small, shallow pits
and chips, medium-size chips near and on base edge.
Circumference shape irregularly ovoid. Cross-sectional shape an
irregular circle, truncated. Base flat with rounded edge. Moderately
formed, quality of finish indeterminate; matte.
W 96. Stone (steatite) sphendonoid weight. Museum Inv. No. 78-31-84
Inv. No. KW 174 J15 UR2
L. 6.745; w. 3.272; h. 2.700; mass 90.30 g.
Yellowish cream with dark greenish-gray mottling. Complete, excellently
preserved. Several minute pits; one small chip on base edge. Shallow
scratch on base in form of an irregular V and a rougher scratch beside it
together can give the impression of a rough English broad arrow.

Top view shows one side curvature slightly fuller than other, ends
truncated but rounded. Side view reveals rounded top and two rounded
ends, one less so and angled inward, each joined to base by bevel, one of
which is somewhat convex. End view shape a truncated circle except for
flattened spot on top that represents a faint facet extending over central
two-thirds of weight's length, and shorter, smoother flat just to one side of
top. Flat base reaches over most of length and width; edge somewhat
sharp. Well formed, very well finished; low to medium polish.
W 97. Stone (magnetite) domed weight. Museum Inv. No. None
Inv. No. KW 5151 M16 UR1
Max. diam. 3.667; min. diam. 3.473; base diam. 2.292; h. 2.925; mass 91.29
  g. + 0.08 g. (bits) = 91.37 g.
Dark gray to black with central band of light inclusions over top and one
side; some iron oxidation products. Nearly complete, moderately well
preserved. Appreciable superficial surface erosion over entire weight.
Many small abraded areas and small, shallow chips; one medium-size chip
on top near edge, another on side surface adjacent to large chip on side near
base.

Circumference shape nearly a circle, barely oblong. Cross-sectional
shape an inverted truncated cone with full, rounded top and faintly convex
sides. Base flat with barely rounded edge. Moderately well formed, well
finished; matte.
Stone (limonite) domed weight. Museum Inv. No. 27-5-87
Inv. No. KW 863 M13 LL3
Max. top diam. 3.751; min. diam. 3.472; max. base diam. 2.508; min. diam.
2.226; h. 3.002; mass 91.61 g.
Black with some dark brownish-red mottling; areas of surface erosion
display iron oxidation products. Complete, well preserved. Superficial
surface erosion over much of top and side surfaces. Approximately
perpendicular to one another and extending from top surface to base are
two "bands" of natural fractures or grooves inclined to plane of base and up
to ca. 1.35 cm. long and 0.1 cm. deep. Material between some fractures has
been lost where two adjacent fractures meet in a V to form grooves. Similar
fractures found around base edge that largely follow "grain" of the stone.
Circumference shape barely ovoid, with a straight length on one side.
Cross-sectional shape a truncated circle with one distinct facet near top.
Base flat; edge fairly sharp. Moderately well formed, very well finished;
matte to high polish.
Inv. No. KW 1737 M15 UL3
L. 5.301; w. 2.813; h. 2.479; mass 91.68 g.
Dark brownish red with blue tinge. Complete, moderately preserved.
Significant surface erosion on base and one side; except for part of top, all surfaces rather densely pitted and chipped, especially base.

Top view shows one side curvature somewhat fuller than other, one end truncated. Side view reveals fully rounded top, one end rounded, other essentially straight and vertical, each joined to base with faintly convex bevel. End view shape essentially a truncated circle with several faint flat spots. Base slightly uneven and covers most of length and width; edge rounded. Well formed and finished; matte to low polish.
W 100. Stone (ilmenite) sphendonoid weight. Museum Inv. No. 22-7-95
Inv. No. KW 3800 M15 LR1
L. 5.119; w. 2.715; h. 2.442; mass 92.43 g.
Dark brownish red with blue tinge; most of surface covered with dark brown. Complete, moderately well preserved. Minute to medium-size pits and chips over much of surface.
Top view shows one side curvature slightly fuller than other, which is barely angular; one end rounded, the other truncated. Side view reveals top curvature somewhat uneven and angular; one end rounded, the other straight and essentially vertical, each joined to the base by means of slightly convex bevel. End view shape basically a truncated circle with flattened areas on top and one side, and a faint bevel on base edge on same side. Base extends over most of length and width, barely convex across both axes; edge rounded. Moderately well formed and finished; matte to low polish.
Stone/metal (hematite/lead) sphendonoid weight. Museum Inv. No. None
Inv. No. KW 5215
L. 5.056; w. 2.747; h. 2.513; max./min. hole diam. 0.626, 0.589; max./min.
lead plug diam. 0.765, 0.520; plug projects 0.65 beyond base; mass 92.01 g.
+ 0.42 g. (plug bits) = 92.43 g (-).
Dark brownish red; extensive black staining on weight, some lead oxidation
products on lead plug in base. Essentially complete, very well preserved. A
few small pits on underside near one end; some minute chips along edge of
hole in base, and several small chips at one end of weight. Oxidized lead
plug expanded and appears like a crudely threaded shaft.

Top view shows one side curvature slightly fuller than other, ends
truncated and somewhat rounded. In side view, top a somewhat angular
curve, ends essentially vertical, slightly convex, and each joined to base by a
barely convex bevel. End view shape a truncated circle with one faint flat
spot near top. Flat base extends over less than half of length and about half
of width, edge rounded to somewhat sharp. Very well formed and finished;
medium polish.

Lead plug in base slightly off-center and projects well beyond base due
to expansion by oxidation.
W 102. Stone (hematite) sphendonoid weight. Museum Inv. No. 11-1-94
Inv. No. KW 3315 N18 UR1
L. 5.233; w. 2.750; h. 2.452; pres. mass 91.67 g (-); cal. mass 92.49 g.
Dark brownish red with blue tinge; black stain over much of surface.
Incomplete, poorly preserved. Extensive pitting, chipping, and exfoliation
over entire surface; one end missing.

Top view shows one side curvature slightly fuller than other, preserved
end truncated and rounded. Side view shows top rounded and preserved
end rounded, angled inward slightly and joined to base by means of a faintly
convex bevel, as was the end not preserved. End view shape essentially a
truncated circle with few flat spots. Base slightly uneven, edges rounded.
Moderately well formed, quality of finish indeterminate; matte.
W 103. Stone (ilmenite [?]) loaf-shaped weight. Museum Inv. No. 33-5-87
Inv. No. KW 935 L10 LR4
L. 3.781; w. 2.855; h. 2.538; mass 92.51 g.
Dark bluish gray with a dark brownish-red patch. Complete, excellently
preserved. Minute to small pits over entire surface and several medium-size
ones, mostly on base.

Top view exhibits gently and unevenly curved sides and one end
truncated and wider than other, with both ends joined to sides with rounded
bevels. In side view, top irregularly rounded, comprising three faintly
rounded facets; each end rounded and joined to base by most faintly convex
bevel. End view shape truncated circle irregularly rounded with several
faintly flat areas. Flat base covers nearly entire length and most of width;
edge rounded. Moderately formed, moderately well finished; matte.
W 104. Stone/metal (hematite/lead) sphendonoid weight. Museum Inv. No. 10-1-94
Inv. No. KW 3299
L. 4.913; w. 2.829; overall h. 2.884; stone h. 2.659; max./min. hole diam.
1.091, 1.074; mass 92.61 g (-).
Dark brownish red with blue tinge; black staining over part of bottom half.
Surface of lead plug exhibits copper and iron oxidation products.
Complete, moderately well preserved. Minute pitting over most of surface,
with small to large pits on both sides and around one end. Small chips on
and near same end, a few at opposite end and on one side, a large one on
base at hole edge; small crack on top near one end. Lead plug in base
complete but cracked, split, and expanded beyond base surface due to
effects of oxidation.

Top view shows one side curvature somewhat fuller than other, ends
truncated. Side view shows top curvature flattens toward one end, ends
barely rounded, essentially vertical, each joined to base with barely convex
bevel. End view shape essentially a truncated circle. Flat base, notably
inclined to body of weight and moderately displaced toward one end,
extends over less than half of length, most of width; edge rounded. Well
formed, very well finished; matte to low polish.

Round hole virtually in center of base contains complete lead plug
protruding well beyond surface of base.
W 105. Stone (hematite) domed weight. Museum Inv. No. 71-31-84
Inv. No. KW 153 J15 UR2
Max. top diam. 3.782; min. diam. 3.566; max. base diam. 2.497; min. diam.
2.383; h. 2.475; mass 93.03 g.
Reddish brown with some darker patches. Complete, moderately
preserved. Minute to large pits cover entire surface; many small chips also
over all surfaces and around ca. one-third of base edge.
Circumference shape circular except for bulge over ca. one-third of
circumference. Cross-sectional shape an inverted truncated cone; planes of
top and base not parallel. Barely convex top merges with side surface in
faint, rounded bevel that is more discernible in some areas than in others.
Base nearly flat with fairly sharp edge. Moderately formed, moderately well
finished; low to medium polish.
W 106. Metal (hematite) domed weight. Museum Inv. No. 31-5-87
Inv. No. KW 774 M11 LL3
Max. diam. 3.290; min. diam. 3.155; h. 2.808; mass 93.17 g.
Brownish red of varying shades. Complete, moderately well preserved.
Superficial surface erosion over small patches on top and side surfaces.
Small and medium-size pits scattered over all surfaces, several large pits on
top and side; several small, shallow chips around top edge, one on side
surface at base edge.

Circumference shape an irregular circle. Cross section reveals sloping,
slightly uneven, barely convex top and essentially vertical sides that round
rather sharply into top and base by means of short bevels with rounded
edges. Base virtually flat; edge rounded. Moderately formed, moderately
well finished; matte to low polish.
W 107. Stone/metal (hematite/tin) sphendonoid weight with metal loop at one end.
Inv. No. KW 2001
Museum Inv. No. 45-5-90
L19 LL4
L. 5.127; w. 2.662; h. 1.988; loop l. ca. 3.576; hole diam. 0.624; mass 94.65 g (+).
Brownish red, possibly with blue tinge; darkest brown to black stain over most of surface except at loop end. Loop concretion gray and cream with iron oxidation products. Complete, poorly to moderately preserved; two pieces of loop reattached. Surface erosion on most of base, some on top and sides, especially in pitted areas. Minute to small pits over most of weight, one medium-size one on top near loop end, large one on base; small to medium-size chips on base edge and here and there. Appreciable volume of material missing from area over top and side near end opposite loop. Loop heavily concreted, broken off where bent at ca. 90 degrees, and at one hole, but reattached and complete.

Top view shows one full side curvature, other nearly as full but angular due to distinct side facet along one-half of length; ends truncated, looped end slightly rounded. Side view shows rounded top, one end straight and vertical, one at loop end barely convex, essentially vertical, and joined to base by means of short, barely convex bevel. End view shape essentially a truncated circle. Flat base reaches over almost entire length, most of width, edge fairly sharp. Well formed and finished; matte.

An oblong, tin/lead alloy suspension loop at one end of weight presumably passes completely through it. Its sectional shape appears circular and of varying diameter, smallest at holes, greatest through central portion of loop's length. Loop pinched somewhat inward toward weight as it issues from both ends of hole, inclined slightly toward base, and extends barely beyond nearer end of weight before bending almost 90 degrees toward base. Hole's axis not quite perpendicular to base's length, but seems essentially parallel to the base. End of hole not obscured by loop and its concretion exhibits wear area around top portion (as weight rests on it base) of its edge. Exposed portion of hole's opposite end somewhat irregular and exhibits what appears to be rather deep (ca. 0.1 cm.), tapering cut curving from its edge toward base.
W 108. Metal (lead) discoid weight. Museum Inv. No. 87-24-86
Inv. No. KW 459 J10 UR2
Max. top diam. 4.367; min. diam. 4.127; max. base diam. 4.576; min. diam. 4.479; max. th. 1.270; min. th. 0.81; max. diam. of hole on top surface 0.641; min. diam. 0.602; max. diam. of hole on base 0.735; min. diam. 0.684; mass 139.51 g (-).

Varying shades of gray and tan. Complete, well preserved. Thin coating of compact corrosion products preserves original surface details. Some minute cracks on top surface at edge; larger one around most of base surface at edge, and another of same size around ca. one-half of side's circumference. One large chip on base edge extends partly onto side; two small exfoliated areas on base near hole.

Circumference shape circular, barely oblong, and essentially concentric to that of base, which is nearly a circle, slightly irregular. Cross section reveals slightly convex, but slightly rough and irregular top; irregular, convex side surface meets top at fairly sharp edge. Base slightly rough, irregular, and concave due to raised lip around fairly sharp edge. Central round hole through thickness tapers from base to top surface. Edge on top surface slightly oblong with four small arcs spaced approximately 90 degrees from one another; minute raised lip around entire circumference of edge. Hole edge on base slightly ovoid with three angular arcs that are continuations of their counterparts on top surface; edge beveled or worn at these arcs with small raised lip in intervening spaces. Moderately formed, quality of finish indeterminate; matte. Visible under low (8X) magnification are groups of straight, parallel striations here and there on base, especially near edge, and groups of much longer, thinner, and shallower curved marks over about one-third of base.

The striations and longer, finer marks would seem to be tool marks left in mold. Notable similarities between this weight and W 108 (KW 298) in terms of general shape, size, craftsmanship, and taper of hole. They were found in same grid square some 1.4 m apart.
W 109. **Metal (lead) discoid weight.**

Inv. No. KW 298

Max. top diam. 4.405; min. diam. 4.209; max. base diam. 4.950; min. diam. 4.732; max. th. 1.40; min. th. ca. 0.95; max. diam. of hole on top surface 0.702; min. diam. 0.615; max. diam. of hole on base 0.797; min. diam. 0.756; line widths on top ca. 0.015; line widths on base ca. 0.011; mass 154.90 g. + 0.58 g. (bits) = 155.48 g.

Light through dark shades of gray and tan. Incomplete, moderately preserved. Thin coating of compact corrosion products preserves original surface details. Some surface erosion and pitting on top and base, more significant pitting on side surface, including several medium-size and large pits and chips. Many fine cracks, especially along incised lines; approximately one-third of base edge chipped away, as is a small portion of base just inside base edge.

Circumference shape slightly elliptical and eccentric to that of base, which is essentially a circle. Cross section shows gently convex top somewhat rough and irregular; irregular, convex sides meet top surface at fairly sharp edge. Base with shallow lip ca. 0.5 cm. wide around circumference slightly concave and uneven with one small, raised patch; edge is rounded. Round hole through thickness essentially centered in top surface and tapers from base to top surface, with slightly elliptical edge and three small, faint arcs spaced approximately 90 degrees apart. Minute raised lip along edge of hole around most of circumference may represent wear, but no distinct wear marks evident under low (10X) magnification. Hole virtually centered also in base surface but rounder than counterpart on top; three arcs around edge are continuations of those on top hole edge, and no raised lips or wear marks evident. Moderately well formed, quality of finish indeterminate; matte.

The top surface crudely incised with 18 thin, shallow, unevenly spaced lines radiating from top hole to edge. Five essentially perpendicular to tangent, remainder issue obliquely from hole in manner of bicycle spokes. Approximately half are curvilinear and half roughly straight. A line of similar nature around perimeter lies just within the edge of top surface and cut by all radiating lines, most of which reach or extend slightly beyond edge of top surface.

Base surface incised with notably finer line in spiral pattern that, starting from near outer edge, makes four irregular clockwise circuits inward toward the hole. Immediately upon completion of fourth circuit, line crosses itself outward into space between two innermost circuits and continues for about three-quarters of circuit. Just beyond termination point (continuing clockwise), is a straight line perpendicular to hole tangent that begins between innermost circuit and hole, and ends after crossing four arcs.
of spiral. Second line 60 degrees farther clockwise lies oblique to hole and also commences between hole and innermost circuit, but crosses only two spiral arcs and ends at the third.

Absent are groups of fine striations like those evident on base surface of KW 459 (W 12).
W 110. Metal (bronze) domed weight. Museum Inv. No. 44-7-95
Inv. No. KW 3840  O17 UL4
Max. top diam. 3.845; min. diam. 3.744; max. base diam. 2.695; min. diam. 2.595; h. 2.740; mass 159.16 g. + 1.33 g. (bits) = 160.49 g.
Dark brownish red to black. Complete, well preserved, except that perhaps 90 percent of surface exfoliated (up to 0.1 cm. in places). One small chip on top edge and one small secondary exfoliation on side surface near base.

Circumference shape a barely irregular circle. Cross-sectional shape an inverted truncated cone with fully rounded top. Portions of side slightly convex, angles between side and base symmetrical in some views. Base flat with fairly sharp edge. Very well formed, quality of finish indeterminate; matte to low polish.
Metal (lead) discoid weight.

Inv. No. KW 1979

Museum Inv. No. None

O14 UL4

Max. diam. 5.910; min. diam. indeterminate; max. th. 2.57; min. th. 1.534;
max. diam. of hole on top surface 0.679; min. diam. 0.637; max. diam. of
hole on base 0.751; min. diam. 0.712; mass 171.80 g. + 0.25 g. (bits) =
172.05 g.

Varying shades of white, gray, and tan. Incomplete, poorly preserved. Thin
coating of compact corrosion products preserves details on better preserved
surface. Extensive surface erosion and exfoliation, most of side and much
of top and base surfaces lost due to severe expansion during oxidation.

Original circumference shape presumably circular or round, but
indeterminate due to loss of much material. Cross section reveals slightly
concave top and side surfaces, while base too distorted to evaluate. Round
hole through thickness tapers from base to top surface; whether centered or
not on either surface indeterminate, again due to loss of material. Hole edge
on top surface exhibits distinct raised lip around entire circumference and
due faint, unevenly spaced arcs. Such arcs also found along somewhat
ovoid hole edge on base surface and appear to be continuations of those on
top. Quality of form and finish indeterminate; matte.

Base and top designated according to taper of hole through thickness.
Smaller hole diameter assigned to top surface, as seems to be the case on W
107 (KW 459) and W 108 (KW 298); therefore, raised lip on top surface.
W 112. Stone (diorite [?]) domed weight. Museum Inv. No. 30-5-90
Inv. No. KW 1917 F21 UL1
Max. top diam. 5.188; min. diam. 5.123; max. base diam. 3.860; min. diam.
3.752; h. 4.094; pres. mass 182.30 g (-); cal. mass 183.25 g.
Light greenish gray. Nearly complete, well preserved. Many small, shallow
pits and chips over entire surface; one notably large chip and exfoliated area
on base at edge.

Circumference shape an irregular circle. Cross section reveals full,
round top merging smoothly with essentially symmetrical, full, rounded
sides. Base flat with sharp edge. Very well formed and finished; matte.
Stone (hematite) domed weight.  
Museum Inv. No. 72-7-92  
Inv. No. KW 2696  
N14 LL2  
Max. top diam. 4.788; min. diam. 4.635; max. base diam. 3.654; min. diam. 3.369; h. 3.063; mass 184.33 g.  
Dark brownish red with blue tinge, and lighter red, parallel veins across central half of top; iron oxidation products extend over much of base and onto side surface in two areas. Complete, well preserved. Some superficial surface erosion on base. Many small and some medium-size pits over top and side surfaces, dense on base; one large pit on side and one on top; many small, shallow chips and pits around base edge.  
Circumference shape barely ovoid. Cross section reveals irregular, gently rounded and sloping top merging smoothly into convex sides, the two surfaces sometimes separated by faint edge. Base slightly uneven but essentially flat; edge rounded. Moderately well formed, well finished; matte to low polish.
W 114. Stone (hematite) domed weight. Museum Inv. No. 8-1-94
Inv. No. KW 3233 N16 ULI
Max. top diam. 4.537; min. diam. 4.404; max. base diam. 3.091; min. diam. 2.977; h. 3.102; mass 185.04 g.
Darkest brownish red with some light areas; some iron oxidation products. Complete, well preserved. Some superficial surface erosion. Minute pitting over entire surface, several medium-size pits on top and side surface and along base edge; one notable vertical gouge on side near top edge.
Circumference shape an irregular circle with possible remnant of one facet. Cross section displays essentially flat, slightly sloping top merging smoothly with convex sides. Base barely convex with fairly sharp edge. Moderately formed, moderately well finished; matte.
W 115. Stone (hematite) domed weight. 

Inv. No. KW 5737

Top l. 5.136; w. 4.011; h. 3.363; base l. 3.638; w. 2.720; pres. mass 182.73 g. + 1.10 g. (bits) = 183.83 g (-); cal. mass 185.24 g.

Dark brownish red. Incomplete, poorly preserved. Extensive surface erosion, pitting and chipping; portion of one end missing.

Circumference shape a faintly faceted ellipse. Longitudinal cross section shows slightly faceted ellipse, especially at intact end, with one long side truncated. Lateral cross-sectional shape viewed from intact end virtually a truncated circle. Base faintly convex with fairly sharp edge. Moderately well formed, quality of finish indeterminate; matte to low polish.

Inv. No. KW 857

Museum Inv. No. 30-5-87

M11 LR1

Max. top diam. 4.301; min. diam. 4.135; max. base diam. 3.690; min. diam. 3.430; h. 3.417; mass 185.64 g.

Brownish red with darker and lighter patches and some light inclusions. Complete, very well preserved. Several small pits, minor chips, gouges, and abraded patches.

Circumference shape irregularly rounded with vestiges of three facets. Cross-sectional shape an inverted truncated cone, planes of top and base nearly parallel; flat top rounds smoothly into slightly convex sides. Base barely convex with fairly sharp edge. Moderately formed, well finished; matte to medium polish.
W 117. Stone (hematite) domed weight. Museum Inv. No. 6-1-94
Inv. No. KW 3279 O18 LL4
Max. diam. 4.294; min. diam. 4.189; h. 3.522; mass 185.68 g.
Dark brownish red with some lighter patches and light inclusions, some
blue-tinged areas. Complete, moderately preserved. Some superficial
surface erosion; minute and small pits over entire surface, several medium-
size and large ones. Small, shallow, chipped patch on base near edge;
various small scratches and abrasions.
Circumference shape round with vestiges of at least three facets. Cross
section exhibits gently rounded top merging smoothly with slightly convex
side surface. Base somewhat uneven and partly rounded with rounded
edge. Moderately formed, moderately well finished; matte to low polish.
W 118. Stone (hematite) domed weight. Museum Inv. No. 7-1-94
Inv. No. KW 3195 N16 UL3
Max. top diam. 4.269; min. diam. 4.158; max. base. diam. 3.478; min. diam.
3.293; h. 3.383; mass 186.74 g.
Dark brownish red with lighter shades and some white inclusions.
Complete, moderately preserved. Some surface erosion; pits of all sizes
over entire surface with large number of medium-size and large ones;
medium-size chips around top edge.
Two-thirds of circumference shape circular, remaining third comprises
two faint but distinct straight lengths oriented ca. 90 degrees to one another.
Cross-sectional shape inverted truncated cone. Top and base planes
virtually parallel, top barely convex, sides slightly more convex, with faintest
traces of bevel here and there between top and sides. Base slightly uneven
and partly rounded; edge rounded. Moderately formed, well finished; matte
to medium polish.
Stone (hematite) domed weight.  
Museum Inv. No. 5-1-94  
Inv. No. KW 3343  
M16 UR1  
Max. top diam. 4.289; min. diam. 4.115; max. base diam. 3.213; min. diam. 2.783; h. 3.346; mass 187.43 g.  
Dark to lighter brownish red. Complete, well preserved. Pits of all sizes over entire surface, two large ones on side surface and one on base at edge. Several small, shallow chips and two medium-size ones on side surface.  
Circumference shape an irregular circle. Cross-sectional shape an inverted truncated cone, planes of top and base surfaces not parallel. Uneven, faintly convex top and sides joined by faint, rounded bevel, and sides merge with base by means of short bevel with smooth edges. Base flat; edge rounded. Moderately formed, moderately well finished; matte to low polish.
W 120. Stone (diorite) domed weight.  
Inv. No. KW 3501  
Museum Inv. No. 21-7-95  
O17 LR1
Max. top diam. 5.872; min. diam. 5.795; max. base diam. 4.281; min. diam. 4.128; h. 4.822; base incision (virtually on the radius) l. 1.890; max. w. 0.066; min. w. 0.035; base incision (adjoining the first) l. 1.369; max. w. 0.062; min. w. 0.022; mass 275.79 g.

Gray tinged with green with black speckles; faint iron oxidation products. Complete, very well preserved. Small pits here and there; minor chipping around base edge.

Circumference shape nearly a circle. Cross-sectional shape a truncated circle. Base flat with fairly sharp edge. Very well formed and finished; matte.

Two lines incised on base, each asymmetrically V-shaped in cross section, intersect near base edge at an angle of precisely 90 degrees. Longer line lies essentially on radius of base and extends inward from near base edge to meet shorter line with no overlap. Under low (8X) magnification, depth of longer line appears relatively consistent except near shorter line, where it becomes shallower. Shorter line deeper in central portion, becoming shallow in symmetrical fashion toward both ends. Edges of shorter line sharper than those of other.
W 121. Stone (hematite) domed weight.

Museum Inv. No. 79-24-86

Inv. No. KW 578

Max. diam. 5.007; min. diam. 4.830; h. 3.622; mass 278.61 g.

Dark brownish red with lighter and darker patches and spots. Complete, well preserved. Entire surface covered with minute and small pits, along with several medium-size ones, especially on base, and two large ones on side surface. Several medium-size chips on base and around edge, one on top edge; shallow crack across part of top near edge.

Circumference shape an irregular circle with traces of several facets. Cross-sectional shape an inverted truncated cone, planes of top and base surfaces essentially parallel. Uneven, barely convex top joins convex side surface at faint but distinct edge. Base essentially flat with rounded edge. Moderately well formed, well finished; matte to medium-high polish.
W 122. Stone (serpentine) domed weight. Museum Inv. No. 76-24-86
Inv. No. KW 571 M11 LL1
Max. top diam. 5.910; min. diam. 5.824; max. base diam. 4.229; min. diam.
3.853; h. 4.766; mass 278.63 g.
Darkest to lighter greens with many light inclusions; iron oxidation products
over much of surface. Complete, very well preserved. Many superficial
scratches and "dents." One minute chip on base edge; large gouge on side
surface near top; three medium-size patches of shallow indentations on side
surface probably resulting from rubbing with harder object.
Circumference shape a faintly faceted circle. Cross section exhibits full,
rounded top merging smoothly with full, rounded sides that are symmetrical
in some views. Base flat with slightly rounded edge. Well formed, very
well finished; medium polish.
W 123. Stone (microcrystalline, fossiliferous limestone) domed weight.

Inv. No. KW 3099

Museum Inv. No. 4-1-94

O17 UL4

Max. top diam. 7.181; min. diam. 6.708; max base. diam. 5.682; min. diam. 4.410; h. 4.255; pres. mass 323.57 g (-).

Off-white with faint reddish-tan tinge; fossil inclusions throughout and one large brown inclusion on side surface. Incomplete, poorly preserved. Unknown portion of piece missing, current "top" surface (with greater diameter) eroded, pitted, bumpy, uneven. About two-thirds of side surface severely pitted and chipped, remaining portion virtually undamaged, perhaps one-fourth of base somewhat pitted and abraded.

Circumference shape ovoid. Longitudinal cross-sectional shape an inverted truncated cone with irregular top; side surfaces meet base at different angles. Lateral cross section similar, except rather large bevel along each long side of base circumference joins side surface and base. Base flat with fairly sharp edge. Moderately formed, moderately well finished; matte to low polish. Polish marks in form of long, thin, parallel striations running parallel to short axis of "base" evident over its entire length and extend up onto sides.
W 124. Stone (diorite) domed weight. Museum Inv. No. None
Inv. No. KW 4165 O17 UL3
Max. top diam. 7.649; min. diam. 7.621; max. base diam. 6.130; min.
diam. 5.944; h. 4.658; base incision (near the radius) l. 1.074; max. w.
0.056; min. w. 0.031; base incision (adjoining the first) l. 0.897; max. w.
0.060; min. w. 0.031; mass 456.48 g.
Light greenish gray. Complete, well preserved. Many small pits on side
surface; small chips over lower side and base.
Circumference shape virtually a circle. Cross section reveals fully
rounded top merging smoothly into fully rounded side surface that is
bilaterally symmetrical in some views. Base flat with fairly sharp edge.
Very well formed and finished; matte.
Two lines incised on base intersect near base edge at an angle of just
over 90 degrees. One with U-shaped cross section lies nearly on radius of
base; its end nearest base edge obscured by chipped area, but one minute
length preserved in chipped area indicates line approached within at least 0.5
cm. of base edge, perhaps closer. May have been cut first, as is overlapped
for 0.183 cm. by second line. Line deeper at chipped patch, shallow at point
of intersection; edges clean, somewhat worn. Second line preserved for
entire length and exhibits V-shaped cross section, deep in central portion
and becoming uniformly shallower toward ends; edges clean, somewhat
worn.
W 125. Stone (hematite) domed weight. Museum Inv. No. 29-5-87
Inv. No. KW 710 N15 LL3
Max. top diam. 6.760; min. diam. 6.654; max base diam. 4.913; min. diam. 4.660; h. 3.830; mass 458.54 g.
Dark brownish red with black mottling here and there. Complete, moderately preserved. Severely pitted and chipped over much of surface, with most pits of medium size.

Circumference shape slightly irregular circle. Cross section displays top and sides rather sharply rounded in smooth curves to base. Flat base somewhat uneven with rounded edge. Moderately well formed, well finished; medium to high polish.
W 126. Stone (diorite [?]) discoid weight. Museum Inv. No. 42-24-86
Inv. No. KW 382 P11 UL1
Max. diam. 8.090; min. diam. 7.774; h. 4.00; pres. mass 460.32 g (-); cal.
mass 462.40 g.
Gray to nearly black top surface, greenish gray sides and base. Incomplete,
moderately preserved. Minute pitting on side surface and dense, shallow
pitting on top and central potion of base, larger pits on periphery of top.
Several medium-size chips on top edge and on base, three large and two
very large ones on base edge. Thin, shallow crack traverses entire disc
obliquely.

Circumference shape nearly a circle. Cross section shows convex,
uneven, slightly sloping top, sides convex to almost straight and vertical.
Base slightly concave, uneven; edge rounded. Moderately well formed and
finished; matte.
Inv. No. KW 477 L11 UR2
Max. diam. 7.551; min. diam. 7.448; h. 6.163; mass 916.70 g.
Light to very dark brownish red. Complete, moderately preserved.
Appreciably pitted and chipped over much of surface.

Circumference shape irregularly circular. Cross-sectional shape
exhibits irregular, fully rounded top and side surfaces that merge smoothly.
Flat base somewhat uneven with rounded edge. Moderately formed, well
finished; matte to medium polish. Polish marks visible across part of top
surface, with those evident on portions of side surface parallel to plane of
base.
W 128. Stone (hematite) domed weight. Museum Inv. No. 2-4-88
Inv. No. KW 1511 L12 LL2
Top l. 7.623; w. 6.856; base l. 5.332; w. 4.944; h. 6.04; pres. mass 923.20 g (-); cal. mass 925.60 g.
Dark brownish red with some black patches. Complete, moderately preserved. Appreciable pitting and chipping over most of surface, including several large concentrated areas. One small natural crack near top of side surface.

Circumference shape irregularly ovoid. Longitudinal cross section reveals sloping, rounded top merging smoothly into rounded sides, but with faint hint of an edge between top and side surfaces at higher end. Irregularly rounded top merging smoothly into seemingly natural flattish area to one side. Base essentially flat over long axis, uneven and convex over short axis; edge fairly sharp. Moderately formed, well finished; medium to high polish. Fine polish marks run parallel to long axis on top surface and in different directions on side surface, while those visible on base are faint, coarse, parallel, and inclined ca. 60 degrees from short axis.
W 129. Metal (lead/bronze [?]) discoid weight. Museum Inv. No. 37-5-87
Inv. No. KW 849 M10 LL1
Max. diam. 8.900; min. diam. 8.227; elliptical plug l. ca. 2.7; w. ca. 1.6;
shaft remnants diam. 0.484 x 0.445, 0.484 x 0.375; shaft remnants distance
center-to-center 0.796; h. 5.564; mass 2,483 ± 2 g (-).
Various shades of gray with off-white lead oxidation products; traces of
copper oxidation products on central elliptical plug. Incomplete, poorly
preserved. All surfaces significantly pitted and corroded with minimal
original surface preserved; impressions in bottom surface suggest
indeterminate amount of material lost.

Circumference shape barely elliptical. Cross section exhibits an uneven,
rounded base surface and an irregular, flatter top surface, with gently
convex to almost straight, vertical sides. Quality of form and finish
indeterminate; matte.

Top surface displays a partly circular, partly angular impression ca.
0.75 to 0.9 cm. wide around ca. two-thirds of its circumference. Center of
top contains two small circular features that appear to be corroded remains
of round shafts of a loop of copper that served as handle or other means of
hanging or carrying the weight.
Stone (diorite [?]) sphendonoid weight.

Museum Inv. No. None
Inv. No. KW 830
L10 LR4

L. 24.95; w. 14.64; h. 14.15; mass 7,632 ± 2 g.

Light gray tinged with light and slightly darker green; most of surface stained various shades of brownish orange. Thin brown vein encircles larger end (nearly half of vein worn off) with branch extending down from top toward base. Complete, moderately well preserved. Small to large pits over most of surface, larger end densely pitted with large, deep pits around its edge. Same edge also exhibits one medium-size chip on top surface and large chip on underside; many slightly smaller chips on base.

Top view reveals one side curvature fuller than other and slightly angular; ends truncated and quite rounded, one much wider than other. In side view, top curvature angular with longer, steeper length extending to weight's wider end, which is convex but straighter than opposite, rounded end. End view roughly triangular with rounded sides and vertices, top vertex smaller and flatter than other two. Base (the largest single surface) quite rounded over length and width. Moderately to well formed; well finished; medium polish.

Asymmetrical profile suggests stylized duck form.
W 131. Metal (bronze) zoomorphic weight. Museum Inv. No. None
Inv. No. Lot 960 J16
L. 1.192; w. 0.738; h. 0.632; pres. mass 1.46 g (-).
Black. Incomplete, moderately well preserved. Several minute pits; surface
thinly cracked on top; part of intact end thinly exfoliated. Opposite
extremity missing; three shallow, linear "dents" or impressions on base at
one edge.

Shape resembles body of waterfowl on flat base with neck and head
broken off, but no details suggestive of wings, feathers, and tail. Well
formed and finished; medium to high polish.

Low magnification (10X) reveals densely spaced small groups of short,
fine, parallel striations oriented obliquely to weight's long axis. Striations
not polish marks, but probably tool marks left in the wax or mold. They
resemble those on W 146 (KW 468) and on KW 3081 (W 144). Those on
W 74 (KW 492) are much longer, wider, and coarser. Quality of form amd
finish indeterminate; matte; solid-cast.
W 132. Metal (bronze/lead) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 5841 N17 UR4
L. 2.488; w. 1.068; h. 1.325; lead plug hole l. 1.222; w. 0.445; depth ca. 0.7; pres. mass 2.03 g (-).
Black; speckles of green copper oxidation products, exposed interior surfaces faintly green-tinged tan. Incomplete, poorly preserved; head and several exfoliated pieces reattached. Small portions of original surface along spine to about mid-back and on base beneath hindquarters. Remainder of surface thickly exfoliated and a thinner layer further exfoliated over head, neck, breast, and right side of body; right side of abdominal wall split vertically and horizontally; forelegs merely stumps. Base and remnants of its original surface distorted due to expansion of lead core (almost completely degraded) during oxidation.

Calf (?), recumbent on left side with legs folded underneath, head turned to right. Tail runs directly from base of spine to right hind quarter where bushy tip curls slightly downward. Underside of weight appears to have included a separate layer of material beneath animal's body from hindquarters to some point forward. Quality of form and finish indeterminate; matte.

Roughly sphendonoid-shaped hole for lead core extends over most of width of abdomen and from just behind forelegs and breast to heel of right hind leg; cavity seems slightly longer and wider than opening.
W 133. Metal (bronze) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 2128 M14 LL3
L. 1.818; w. 1.431; h. 0.536; pres. mass 1.23 g (-); est. mass 3.74 g.
Black. Incomplete, moderately preserved. Significant surface erosion over
entire surface. Front and left side of head exfoliated, though bulb of left eye
remains; tip of left wing missing, slightly more of right wing missing.
Fly, at rest, no legs. Vestiges of two bulbous eyes are the only
discernible head details. Three incised parallel lines placed obliquely on top
of each wing. Back exhibits six incised equispaced lines most of which run
along full length of dorsal axis from base of head to tip of abdomen.
Underside flat from wing tips to head. Well formed and finished; matte;
solid-cast.
W 134. Metal (bronze) zoomorphic weight. Museum Inv. No. 42-5-87
Inv. No. KW 873 N15 LL1
L. 2.140; w. 1.203; h. 1.421; pres. mass 1.94 g (-); est. mass 5.48 g.
Black. Nearly complete, well preserved. Beak reattached. Superficial
surface erosion over entire surface; minor pit on right side of beak;
underside of tail, tip of right wing, and extremity of upper beak chipped;
two deep cracks in beak are the beginning of exfoliation; tip of tail and left
eye missing.

Waterfowl (grebe?) at rest with head up and pointed forward, head and
neck pulled slightly into body, elongated and pointed bill open. Underside
essentially flat from breast almost to tip of tail, where slightly uneven. Well
formed and finished; matte; solid-cast.
W 135. Metal (bronze) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 2736 J15 UR4
L. 2.728; w. 0.795; h. 1.115; pres. mass 4.26 g (-); est. mass 7.47 g.
Black. Nearly complete, poorly preserved; exfoliation at left ear and extremity of hindquarters reattached. Entire surface heavily eroded and possibly exfoliated except extremity of hindquarters, which exhibits only superficial erosion. Small chip on left side of body; exfoliation at left ear, on right foreleg, and on right rear leg; left ear and both forelegs missing; right ear vestigial.
Bull, recumbent on abdomen with forelegs folded underneath and head turned slightly to right. Faint hump on top of shoulder blades; vestigial hind legs and tail evident by faint raised surfaces, perhaps never rendered. Underside flat from hindquarters to fore knees. Quality of form and finish indeterminate; matte; solid-cast.
W 136. Metal (bronze) zoomorphic weight.
Inv. No. KW 237
L. 2.181; w. 1.298; h. 1.487; pres. mass 6.62 g (-); est. mass 9.38 g.
Dark gray; various shades of green copper oxidation products here and there. Nearly complete, poorly preserved. Significant surface erosion and some exfoliation over most of surface. Front extremity of head, side of right rear foot, and base beneath left foreleg chipped away.

Frog, seated, leaning forward with head elevated and pointed upward, hind legs tucked beneath. Forelegs are held against body, smoothly bent and curved, left placed faintly farther forward. Hind legs each form angle of ca. 30 degrees with spine. Discrete base slightly convex, extends from base of spine to just forward of and between forelegs. Quality of form and finish indeterminate; matte; solid-cast.
Metal (bronze) zoomorphic weight.  

Inv. No. KW 4504  
Museum Inv. No. None  
M16 UL2  
L. 2.347; w. 1.114; h. 1.322; pres. mass 5.22 g (-); est. mass 9.55 g.  
Black; various greens of copper oxidation products. Nearly complete, poorly preserved; various exfoliated pieces reattached. Original surface, preserved only on right side between tail and head, is heavily pitted and eroded. Remainder of original surface thickly exfoliated, with a second thick exfoliation over much of underside. Exposed subsurface on top displays herringbone pattern down spine; entire left foreleg and parts of right ear and foreleg missing.  

Bull, recumbent on left side, legs folded underneath, head turned sharply to right. Small hump on top of shoulder blades; tail curves up onto right hind quarter, bushy tip curling downward. Underside flat from level of right rear heel to fore knees. Quality of form and finish good; matte to medium polish; solid-cast.
W 138. Metal (bronze/lead) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 4119
L. 2.339; w. 1.903; h. 1.444; pres. mass 9.70 g. + 0.10 g. = 9.80 g (-).
Brownish-red to light brown; green copper oxidation products and off-white
lead oxidation products. Incomplete, poorly preserved. Surface of what
could be remnants of copper alloy shell, and interior, extensively cracked
and split due to expansion of lead core during oxidation.

Quality of form and finish indeterminate; matte.
W 139. Metal (bronze/lead) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 4943 M19 UR1
Max. h. 2.161; base diam. 1.403 x 1.357; head l. 1.496; pres. mass 10.28 g
(-).

Black; copper oxidation products over much of neck, and others of lead on
head and base. Incomplete, moderately to moderately well preserved.
Surface erosion and minor pitting over entire head, and one side and back of
neck. Thin exfoliation around circumference near base edge; one long edge
of top of head chipped, front extremity of head, or muzzle, chipped and
pitted. Approximately one-fourth of base circumference chipped away, and
what appear to be oxidation products between bronze shell and lead plug on
base also chipped away around ca. two thirds of circumference. Thin crack
in bronze shell extends up front of neck from base edge, and shorter one
extends up from the base edge toward right ear. Surface of plug in base
corroded, eroded, and pitted, but not extensively.

Head and neck of dog or some other canine, stylized, with wedge-
shaped head and roughly conical neck. Top view shows wedge-like head
with semicircular concavity where spine would meet skull, between ears,
and taper forward to damaged nose and mouth. Base an irregular circle.
Ear tips at each rear vertex of head missing; each eye represented by crude
V-shaped cut into one of long top edges of head. Front view shows right
side of animal's neck slightly convex, its left side somewhat concave at
head/neck joint, as neck flares notably outward from that point toward base;
base edge slightly rounded. Side view reveals flat head, which forms right
angle with back of head; back of neck somewhat convex like its right side,
while throat also convex but angles outward toward base edge from lower
jaw/throat junction. Base now somewhat concave due to combination of
raised ridge of oxidation products between shell and lead core, and to
corrosion of core surface; surface possibly originally flat or plug only
slightly recessed from level of shell. Moderately well formed, well finished;
matte.
Metal (lead) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 3845 O17 LL2
L. 3.067; w. 1.923; h. 1.646; mass 10.56 g. + 0.07 g. (bits) = 10.63 g (-).
Gray in various shades; greens of copper oxidation products. Incomplete,
poorly preserved. Surface of what could be remnants of copper alloy shell
and interior extensively cracked and split due to expansion of lead during
oxidation; perhaps one-third of object lost. Remains of what could have
been underside distorted and concave. Compact corrosion layer exhibits
many copper oxidation products; abundant lead oxidation products and
some recrystallized copper in cracks and fissures. Notably light for size.
Circumference shape roughly sphendonoid but with nearly half of
length missing. Longitudinal cross-sectional shape shows excessive height
or thickness compared to other sphendonoid weights, thus distinctly
"humped" shape. Uneven underside may have measured less than half of
weight's length and width. Lateral cross-section now exhibits flattened top,
rounded bottom, and irregular sides. Quality of form and finish
indeterminate; matte.

Possible identification as portion of waterfowl's body, missing breast,
neck, and head. Pointed end of weight would thus represent fowl's tail.
W 141. Metal (bronze) zoomorphic weight. Museum Inv. No. 29-24-86
Inv. No. KW 350 K14 LR3
L. 2.219; w. 1.150; h. 1.672; pres. mass 8.33 g (-); est. mass 11.21 g.
Black with small spots of green copper oxidation products. Complete,
moderately preserved. Entire surface significantly eroded. Exfoliation over
almost entire head and right side of body, continuing to front and onto
underside, with two other small areas on left side of underside at front and
tip of tail; details of eyes and bill vestigial.
Duck at rest with bill pressed against breast, tail slightly fan-shaped.
Underside flat from breast to end of tail. Quality of form moderate to good,
as head and neck seem somewhat large for body; moderately well finished;
low polish; solid-cast.
W 142. Metal (bronze) zoomorphic weight. Museum Inv. No. 43-5-87
Inv. No. KW 727 N15 UR2
L. 2.349; w. 1.395; h. 1.644; pres. mass 3.26 g (-); est. mass 11.29 g.
Black. Nearly complete, moderately preserved; right fore knee reattached.

Surface erosion over almost entire weight. Minor pitting and
exfoliation immediately below left ear; forward extremity of right rear leg
chipped, dewlap eroded and chipped, perhaps one-third to one-half missing
if original shape was rounded. Horn buds, right eye, and ear vestigial; left
ear missing. Mass is light for its size.

Newborn calf, recumbent on left side with legs folded underneath, head
turned back to right such that mouth touches right hind quarter as if
cleaning itself. Horn buds on top of head, ear well back on head, large
dewlap at breast, hint of a right eye, left perhaps never rendered; no
evidence of tail. Underside is somewhat irregular and convex, extends from
level of right rear heel to fore knees, including space between right side of
abdomen and right legs. Cavity in underside immediately beneath right legs.
Quality of finish indeterminate; matte; solid-cast.
W 143. Metal (bronze/lead) zoomorphic weight. Museum Inv. No. None
Inv. No. KW 220 O14 LL2
L. 3.879; w. 2.921; h. 2.585; lead plug l. 0.880; w. 0.774; pres. mass 19.52 g (-).
Copper alloy black, lead gray; green copper oxidation products here and there. Incomplete, poorly preserved; two pieces of degraded alloy reattached to back of neck just below top of head. Original surfaces only from base of throat up onto top of head and on exterior and bottom surfaces of rear legs, and all pitted and/or eroded. Left eye and outline of right only head details preserved; lower left foreleg missing. Surface of lead plug on underside pitted, eroded, and does not quite reach level of base.

Frog, seated, leaning forward with head elevated and turned slightly to right, hind legs tucked beneath. Forelegs curve outward from body, right placed somewhat farther forward than left. Essentially flat, triangular base comprises lower abdomen and hind legs, each of latter meeting spine at an angle of 30 degrees. Quality of form and finish indeterminate; matte.

The nature of weight's interior and remnants of lead core indicate latter occupied nearly all of triangular base and reached up to between forelegs, possibly into the throat.
W 144. Metal (bronze) zoomorphic weight. Museum Inv. No. 25-24-86
Inv. No. KW 335 K14 LR3
L. 3.238; w. 1.173; h. 1.651; pres. mass 16.07 g (-); est. mass 20.00 g.
Dark gray to black. Complete, moderately preserved; exfoliation at
hindquarters reattached. Entire surface significantly eroded and exfoliated;
one large pit on nose; thick exfoliation at fore knees and extremity of
hindquarters; cracks on upper hindquarters and along right foreleg. Tip of
left ear missing; right ear vestigal.

Bull, recumbent on left side with legs folded beneath, head following
natural curvature of body. Small but distinct hump on top of shoulder
blades; tail extends up over right hind quarter onto back, bushy tip overlying
spine. Head displays stubs of horns or horn buds; eyes, right ear, and details
of nose and mouth vestigial. Underside flat from fore knees to base of
spine. Quality of form and finish indeterminate; matte; solid-cast.
Metal (bronze/lead) zoomorphic weight. Museum Inv. No. 3-1-94
Inv. No. KW 3081 N18 LL2
L. 4.228; w. 1.866; h. 2.280; hole l. 1.474; w. 0.817; pres. mass 26.77 g (-).
Black. Complete, poorly preserved; right ear reattached in two pieces.
Surface extensively eroded and/or exfoliated; details of eyes, muzzle, and
front paws vestigial; small portion of right rear paw missing. Lead core
surface shows compact corrosion layer, split and cracked. Hole in
underside for core irregularly elliptical, chipped and eroded at forward end
and around edge beneath right side of animal.

Lioness, recumbent on abdomen with hind legs gathered beneath, front
paws extended forward, head pointed forward. Tail curls up over right hind
quarter onto back and overlies spine. Underside from hindquarters to front
paws and between them uneven, right hind leg slightly raised. Moderately
formed, finish indeterminate; matte to medium polish.

Lead core in elliptical hole in underside does not quite reach level of
underside.

Low magnification (10X) reveals small groups of short, fine, parallel
striations oriented in various directions on original surfaces. Striations not
polish marks, but probably tool marks left in wax or on mold. They
resemble those on W 146 (KW 468) and on W 131 (Lot 960). Those on W
74 (KW 492) much longer, wider, and coarser.
Metal (bronze/lead) zoomorphic weight. Museum Inv. No. 54-5-90
Inv. No. KW 2050 K19 UL4, in amphora KW 2038
L. 5.486; w. 2.303; h. 3.394; h. overall 3.664; lead plug l. 2.673; w. 1.458;
pres. mass 54.64 g. + 0.33 g. (bits) = 54.97 g (-).
Black. Incomplete, poorly preserved; right foreleg, right rear heel, and
many exfoliated pieces reattached. Entire surface extensively eroded,
though eyes are discernible. Most of left side, part of head, and some of
base exfoliated; right ear and horn, left ear, part of muzzle, forward portion
of right rear leg, and most of underside of hindquarters missing. Minor
splitting of edge of hole in underside due to lead core's expansion from
corrosion; medium-size chip in front edge of core.

Bull, recumbent on left side with legs folded underneath, head
following natural curvature of body. Small hump on top of shoulder blades;
dewlap; long tail rises up over right hind quarter and extends across spine
and half-way down left side. Base of spine prominent in manner of old or
underfed animal, though this appearance may be due to effects of
exfoliation. Underside originally flat, extending from right heel to fore
knees but not between them. Moderately well formed, as head and neck a
bit large for body; finish indeterminate; matte.

Irregularly elliptical lead core claims ca. two-thirds of length and nearly
entire width of underside, from which it protrudes significantly.
W 147. Metal (bronze) zoomorphic weight. Museum Inv. No. 55-24-86
Inv. No. KW 468 K14 LR1
L. 5.595; max. w. 1.745; h. 2.731; pres. mass 80.70 g (-); est. mass 85.24 g.
Darkest green with small black patches and speckles. Complete, very
well preserved. Minor surface erosion except on breast, where original
surface from beneath chin to legs lost. Small pit almost precisely at right
eye, medium-size pits along interior of front left leg probably from faulty
casting; half of top surface of right front paw exfoliated; forelegs bent
slightly upward.

Sphinx, recumbent with hind legs gathered beneath, front legs extended
forward, head pointed forward. Anthropomorphic facial features include
thick lips, broad nose, and large, fleshy ears. Lion body characterized by
smooth, featureless mane that meets shoulders and back in scallop pattern;
tail extends up over right rear leg onto back, tufted tip overlying spine.
Underside flat from base of spine to tips of front paws, but not between
paws. Well formed and finished; matte to low polish; solid-cast.

Low magnification (10X) reveals small groups of short, fine, parallel
striations oriented in various directions on original surfaces. Striations not
polish marks, but probably tool marks left in wax or on mold. They
resemble those on W 144 (KW 3081) and on W 131 (Lot 960). Those on
W 74 (KW 492) are much longer, wider, and coarser.
W 148. Metal (brass/lead) zoomorphic weight. Museum Inv. No. 2-1-94
Inv. No. KW 3292 N18 UR3
L. 8.301; max. w. 3.352; max. h. 4.032; original max. h. ca. 3.764; pres.
mass 171.29 g. + 0.16 g. (bits) = 171.45 g (-).
Black through shades of gray; green copper and off-white lead oxidation
products. Incomplete, poorly preserved; several exfoliated pieces
reattached. Most of surface eroded and/or thickly exfoliated. Large, wide
cracks over entire weight, except head and neck, due to extensive expansion
of lead core from oxidation; underside also rendered uneven, with no two
legs now on same plane. Most of core present and protrudes beyond
underside of body.

Young lion, recumbent on abdomen with hind legs gathered beneath,
front paws extended forward, head pointed forward. Short mane terminates
on spine at shoulder blades; tail extends around right hind quarter and curls
up right flank to overlie spine and small part of left hind quarter. Preserved
details include exterior portion of right ear and spiral interior of left; right
eye, nostril, and bulb of left eye, whiskers on upper lips and cleft between
lips, lower lip and chin, short ruff from left ear to beneath right jaw, incised
V-shaped marks and vertical zig-zag patterns on breast; four toes on each
forepaw and possibly three on left rear, and four ribs on right rib cage.
Underside presumably originally flat from tail to tips of forepaws. Quality
of form and finish seem good; matte.

Lead core appears to fill at least entire chest and abdomen.
W 149. Metal (bronze/lead) zoomorphic weight. Museum Inv. No. 81-24-86
Inv. No. KW 582
L11 LR2
Max. diam. of top of base 5.821; min. diam. 5.542; base h. 4.427; overall h.
6.51; bronze wall th. on top and on side near top ca. 0.10; bronze wall th.
near center of height ca. 0.075; l. of calves ca. 2.2; w. of calves ca.
0.9–0.95; pres. mass 409.70 g (-).
Original bronze surfaces various greens and other stains of copper oxidation
products, lead gray with typical off-white oxidation products. Incomplete,
cowherd and cows moderately preserved, base poorly preserved; cowherd's
right forearm and many pieces exfoliated from base reattached. Entire
surface of cowherd eroded and/or exfoliated. Cowherd's cap, right ear,
parts of right eye, nose, mouth, and tight forearms preserved; both ears and
right thumb vestigial; part of left foot missing. Surfaces of both calves
significantly eroded, some exfoliation. Calf on cowherd's left missing part
of right ear, extremity of hindquarters exfoliated and chipped. Second calf
missing most of left ear. Original presence of fourth figure, now lost,
presumably another calf to the cowherd's right, suggested by small hole in
top of base and elongated elliptical impression with one pointed end. Its
size consistent with those of calves and its position suggestive of
symmetrical composition. What appears to be lead and lead oxidation
products protrude through hole, but whether they represent part of lead
within base or remnants of lost figure is indeterminate.
Perhaps one-fifth of base's material missing. Almost all extant bronze
severely split, cracked, and exfoliated. Lead and its oxidation products
abound within copper alloy shell.
Bucolic group comprising kneeling cowherd, two recumbent calves,
and a fourth figure now missing, mounted on large bronze base with lead
core. Cowherd's face exhibits large almond-shaped right eye and socket
that extend well around side of face; nose seems to have been quite broad
and flat; ears large and protruding. A beret-like cap crowns head. Cowherd
hunch-backed and kneeling on left knee and lower leg, sole of left foot or
shoe visible under left buttock. Right thigh and knee close against torso;
left arm and hand rest on left thigh and knee; right arm extends out and
downward, with hand and fingers delineated rests on ground. Overall
composition one of bucolic serenity.
Calf to cowherd's left rests on its right side, head facing man, all legs
folded underneath; tail rises up and rests on left hind quarter, tip curling
downward. Second calf recumbent on left side with head turned toward
first calf; all legs folded beneath; tail rises up over right hind quarter to run
parallel to spine and terminate at bushy tip curled toward first calf.
Base circumference a slightly irregular circle; cross-sectional shape
appears to have been a hollow cylinder with gently domed top and concave
sides. Thin-walled bronze base filled with lead of unknown overall dimensions.

Quality of form and finish of entire piece quite good, judging from level of detail; matte.
PAN-BALANCE PANS

Metal (bronze?) pan-balance pans in wooden case. Museum Inv. No. None
Inv. No. KW 4167

Pan est. max. diam. 9.5; h. 0.7.
Wooden sleeve exterior pres. l. 12.6; th. 2.7.
Wooden sleeve interior recess l. 9.5; w. 1.1.

Pans incomplete, preservation largely indeterminate, as mostly covered by
wooden case. Single exposed portion of bottom pan's underside
uniformly covered with thin concretion, with one crack through concretion
and at least bottom pan. Upper surface of top pan exposed only in three
small areas; one exfoliating, one very mushy under lightest touch of brush,
while third, one nearest one "end" of wooden case, clean and intact. Rim
exposed and thinly concreted here and there. Case incomplete, poorly
preserved. Surface eroded and riddled with shallow tared trails; no original
edges. Thin crack in case appears to follow circumference of pans for ca.
3.0-3.5 cm. at wider end. Wood collapsed into top pan's bowl.

Two or possibly three balance pans nested within one another inside
wooden sleeve. Pans round and shallow; flat bottoms rise at rounded angle
to sides. No evidence yet of how pans suspended. Wood species of case
currently unidentified; grain runs essentially parallel to current long axis of
case. Quality of form and finish indeterminate.
Metal (bronze) pan-balance pans. Museum Inv. No. None
Inv. No. KW 4519 N18 UL4
Top pan diam. ca. 10.0; depth ca. 0.35–0.40; th. indeterminate; rim th. near
bent and split point ca. 0.040; bottom pan diam. and depth presumably those
of top; th. 0.064–0.127 near center of pan diameter, ca. 0.075 at bottom/side
transition point; rim th. ca. 0.045; suspension hole diam. 0.133 (max. diam.
at top surface 0.205), with two more holes evident some 85 to 90 degrees
to either side of this hole.
Both pans incomplete, poorly preserved. Top pan: ca. 140 degrees of
circumference and one-half of surface area missing; extant surfaces
corroded, exfoliated, or covered with copper oxidation products and
encrustation. Side bent sharply inward at one point, where metal is thus
split, and rest of side wall either bent inward or flattened outward. Bottom
pan: approximately one-half preserved, with side wall bent either inward or
flattened outward. Except for one small relatively clean patch, underside
covered with encrustation, as is most of exposed upper surface.
Two balance pans one nested within the other, originally round with
flat bottoms and shallow sides; bottoms curve smoothly into sides that angle
outward at ca. 114 degrees; nature of both rims indeterminate. One hole in
top pan appears to be for suspension, especially in view of what appear to
be two others (currently filled with encrustation, so identification is not
conclusive) of similar diameter and distance from the side wall, roughly 85
to 90 degrees to left and right of hole. Therefore the top pan (and so too
the bottom one) was probably suspended from four points. Quality of form
and finish indeterminate.
Metal (bronze) pan-balance pan fragment
Inv. No. KW 4811
Museum Inv. No. None
N18 LR3
L. overall 9.032; top fragment diam. ca. 10.0, depth ca. 0.34; l. 8.895, represents ca. 127 degrees of original circumference; max. w. 3.538; th. 0.136; rim th. indeterminate; bottom fragment diam. and depth presumably those of top; l. ca. 8.759; max. w. 3.479; th. 0.172; rim th. indeterminate; possible remnant of suspension hole diam. 0.251.
Moderately to moderately well preserved. Surfaces corroded, exfoliated, or covered with copper oxidation products and encrustation. Cleanest and best preserved surfaces visible along bottom/side transition area of top fragment.

Fragments of two balance pans, one nested within other. Originally round with flat bottoms and shallow sides; bottoms curve smoothly into sides that angle outward at ca. 115 degrees; nature of both rims indeterminate. Only one possibly partial suspension hole located at one broken end in position relative to the rim that is consistent with those on KW 4519. Quality of form and finish indeterminate.

May be part of KW 4519 as diameters of both pairs of pans sufficiently approximate one another as does angle at which side walls inclined the pan bottoms. Unfortunately, damaged and encrusted broken ends of pans do not allow for definitive attribution. Moreover, absence of suspension hole in top pan argues against such an association.
APPENDIX D

CATALOG OF WEIGHTS FROM CAPE GELIDONYA

W 1 in. Stone (limonite) domed weight. Museum Inv. No. None
Publ. No. W 1 (FN No. 184) M II (just outside in sand)
Max. diam. 1.436; min. diam. 1.259; h. 0.928; mass 3.41 g.
Dark brownish red. Complete, excellently preserved.

Top view shape irregularly rounded. Cross-sectional shape reveals
irregular and faceted, truncated circle. Base flat with sharp edge. Quality
of form indeterminate, very well to excellently finished. Abrasion marks
clear on base and on nine distinct facets around side of piece, usually
inclined 60 degrees, sometimes 30 degrees, from base surface. Remainder
of surface exhibits no evidence of working, but entire surface highly
polished.
W 2n. Stone (hematite) sphendonoid weight. Museum Inv. No. 248
Publ. No. W 2 (FN No. 182) M II (just outside in sand)
L. 2.746; w. 1.277; h. 1.004; incised mark l. 0.804; incised mark max. w.
0.08; incised mark depth ca. 0.06; mass 9.34 g.
Dark brownish red with blue tinge; black stain over virtually entire
surface. Complete, moderately well preserved. Some surface erosion and
minute pitting on all surfaces; two small chips at one end.
Top view shows almost bilateral symmetry, ends truncated and faintly
rounded. In side view top curvature somewhat flattened, ends essentially
straight and vertical. End view shape a truncated circle with small flat
spot near the top. Flat base reaches over most of length and width, edge
sharp. Moderately well formed, well finished; matte to medium polish.
Near mid-length single, straight, off-center line incised almost parallel
to weight's short axis. Cross-sectional shape an asymmetrical V with
edges slightly chipped here and there.
W 3n.  Stone (dolomitic marl [?]) domed weight.  Museum Inv. No. None
Publ. No. W 3 (FN No. 185)  M II (just outside in sand)
Max. diam. 1.726; min. diam. 1.716; h. 1.444; mass 9.43 g.
Dark cream; dark tan stain may be copper oxidation products. Complete,
excellently preserved.

Circumference shape virtually a circle. Cross-sectional shape a
truncated circle. Base flat; edge rounded. Excellently formed, very well
finished; matte.

Weight essentially truncated sphere.
Stone (hematite) domed weight.

Publ. No. W 4 (FN No. 292)

Max. diam. 1.630; min. diam. 1.582; h. 1.416; mass 10.19 g.

Shades of brownish red; some speckles of copper oxidation products.

Complete, very well preserved. Some superficial surface erosion, especially on base; several small to medium-size pits, especially on base.

Circumference shape an irregular circle. Cross section reveals an irregular, truncated circle. Base faintly convex, edge rounded.

Moderately well to well formed, well finished; matte.

Weight essentially truncated sphere.
W 5n Stone (hematite) domed weight
Publ. No. W 6 (FN No. 392)
Max. diam. 1.8; h. 1.8; mass 12.30 g.
Metal (bronze) cylindrical weight.  
Museum Inv. No. 13-112-3.17  
Publ. No. W 5 (FN No. 86)  
M I (old G 21)  
L. 2.481; w. 1.264; h. 1.065; pres. mass 10.13 g (-); est. mass 14.79 g.  
Dark gray to black; almost completely covered with copper oxidation products. Incomplete (?), poorly preserved. Entire surface eroded, densely pitted, and possibly chipped and exfoliated.  
“Top” and “side” view shapes irregular oblong rectangles with uneven, somewhat rounded sides and ends. End view shape roughly elliptical to rectangular with rounded sides and corners. No true base. Quality of form and finish indeterminate; matte.  
Shape resembles squarish to elliptical cylinder. Possibly a section from bronze pick or other similar tool; probably not a weight.
Stone (dolomitic marl [?]) sphendonoid weight. Museum Inv. No. None
Publ. No. W 64 (1987 survey) M II (just outside in sand)
L. 3.157; w. 1.738; h. 1.401; mass 18.09 g.
Off-white with some tan patches; copper oxidation products over most of
surface. Complete, moderately well preserved. Surface erosion and/or
very thin exfoliation over virtually entire weight.

Top view shows arc on one side, the other flattened through central
portion, with both displaying tighter curvatures near ends; one end
rounded, other slightly pointed. In side view, top curvature quite smooth
but somewhat flattened; ends rounded, one more so than other. End view
reveals truncated circle with flattened top and irregularly rounded sides.
Base covers most of length and width, slightly concave over both axes;
edge rounded. Moderately formed, quality of finish indeterminate; matte.
Metal (bronze) conical weight.          Museum Inv. No. 13-112-5.26
Publ. No. W 8 (FN No. 84)             M
Max. base diam. 1.550; min. base diam 1.413; h. 2.535; pres. mass 17.80 g
(-); est. mass 20.42 g.
Black; nearly entirely covered with copper oxidation products. Complete
(?), moderately well preserved. Uniform surface erosion over entire
weight; a few small pits on "base" and side surfaces.

"Top" view shape irregularly ovoid. Side view shape rough right
triangle with convex base and uneven sides. Lateral sections range from
irregularly ovoid to irregularly triangular. "Base" convex and uneven,
edge sharp to rounded. Quality of form and finish indeterminate; matte.

Shape almost "right cone" with convex base. Probably scrap bronze
rather than weight piece.
Stone (hematite) sphendonoid weight.

Museum Inv. No. None

Publ. No. W 10 (FN No. 85)

L. 2.663; w. 1.752; h. 1.410; mass 20.48 g.

Brown to brownish red. Complete, well preserved. Superficial surface erosion over all but top and one side surface. Few minute to small pits there and there, with medium-size one on top surface and one on base; one medium size-chip on top at one end.

Top view shows rectangle with rounded sides and corners, one end slightly narrower than other. Longitudinal cross section reveals faintly convex top and rounded ends. Lateral cross section rectangular with rounded sides and corners. Base reaches over virtually entire length and width, slightly convex over both axes; edge rounded. Well formed and finished; matte to low polish.

Weight essentially flattened cylinder or loaf-shaped.
Stone (hematite) lentoid weight. Museum Inv. No. None
Publ. No. W 9 (FN No. 336) G (above wooden beam)
Max. diam. 2.599; min. diam. 2.434; h. 1.347; mass 20.53 g.
Brownish red; profusion of copper oxidation products. Complete, well
preserved. Some small to large pits over entire surface; base edge exhibits
what could be three chips.

Circumference shape a rough, nearly square rectangle with rounded
sides and corners. Cross section shows an off-center, rounded top sloping
steeply to distinct edges, slightly convex, irregular sides that angle inward
to base. Base flat, slightly uneven; edge rounded. Moderately formed and
finished?; matte.

Weight resembles top of larger piece that has been chipped off and its
underside then smoothed, though no abrasion marks evident on base.
What may be chips around base edge may be result of working, or
damage, or feature of original "blank" prior to working.
W 11n. Stone (hematite) pyramidal weight. Museum Inv. No. None
Publ. No. 11 (FN No. 219) G (under strange stone G 5)
L. 2.423; w. 1.925; h. 2.170; mass 25.79 g.
Brownish red with blue tinge; dusted with iron oxidation products.
Complete, well preserved. Uniform surface erosion; several small and
medium-size pits and few large ones.
Top view shape truncated ovoid with nearly straight sides.
Longitudinal cross-sectional shape an irregular, truncated circle with short,
straight length. Lateral cross-sectional shape roughly triangular with
rounded vertices and base. Base nearly flat, somewhat uneven; edge
rounded. Poorly formed, well finished; matte.
Shape very roughly pyramidal with two opposing, quite small faces
that do not meet at top of weight; base rounded.
Stone (hematite) domed weight.

Museum Inv. No. None

Publ. No. W 12 (FN No. 472)

Max. diam. 2.152; min. diam. 2.122; h. 2.017; mass 26.05 g.

Brownish red with a faint blue tinge over about one-half of surface area.

Complete, moderately preserved. Some superficial surface erosion on portion of side surface; appreciable minute to medium-size pits and chips over entire surface.

Circumference shape irregularly circular. Cross section shows uneven, convex top joined to sides with crude, faint, rounded bevel; straight, somewhat uneven sides joined to base by same type of bevel. Base convex; edge rounded. Moderately formed and finished; matte.
Publ. No. W 7 (FN No. 87) M I (old G 22)
L. 3.981; w. 1.150; h. 2.124; pres. mass 15.51 g (-); est. mass 26.89 g.
Entire surface covered with copper oxidation products. Incomplete (?),
poorly preserved. Entire surface eroded; some small to medium-size pits,
one very large one; possibly chipped and exfoliated.
“Top” view shape resembles wedge with wider end irregular and
rounded, two sides uneven. Side view shows “top” slightly concave,
even, with opposite surface and ends irregular and uneven. End view
shape roughly biconvex with all surfaces irregular, one end sharper than
other. No true base. Quality of form and finish indeterminate; matte.
Probably scrap bronze rather than weight piece.
Stone (hematite) sphendonoid weight.  
Museum Inv. No. None  
Publ. No. W 13 (FN No. 168)  
M II (just outside in sand)  
L. 3.622; w. 1.940; h. 1.668; mass 27.98 g.  
Darkest brown to black. Complete, very well preserved. Superficial  
surface erosion associated with minute pits at both ends and along one  
side; minute pits over base.  
Top view reveals one side's curvature smoother, fuller, and more  
angular than other; ends rounded, one more blunt than other. In side  
view, top curvature slightly angular, ends convex, and bevels joining ends  
to base faintly convex. End view shape a truncated circle with few faint  
flat spots. Flat base extends over most of length and width; edge  
somewhat rounded. Well formed, very well finished; medium to high  
polish.
Stone (hematite [?]) sphendonoid weight.  
Museum Inv. No. None  
Publ. No. W 14 (FN No. 329)  
G (above wooden beam)  
L. 2.769; w. 1.967; h. 1.781; mass 28.79 g.  

Dark brownish red; iron oxidation products over most of surface.  
Complete, moderately preserved. Superficial surface erosion over ca. one-half of weight; minute to medium pits and chips over most of surface, and one large pit on side surface.  

Top and side view shapes rectangular with rounded corners and slightly convex sides and ends; one end somewhat wider. End view shape irregularly elliptical to irregularly circular. No well-defined base.  

Moderately formed, moderately well finished; matte.  
Weight essentially a cylinder.
W 16n. Stone (hematite) pyramidal weight.
Publ. No. W 15 (FN No. 213)
L. 2.476; w. 2.144; h. 2.169; mass 29.42 g.
Light brownish red; extensive black staining and iron oxidation products.
Complete, moderately preserved. Some surface erosion on base. Two small pits one on side surface; a few shallow, medium-size chips on top and one side. Much of surface thinly exfoliated.
Top view shows rough rectangle with rounded sides and corners. Side and end views show rounded top and one side, and one side angled outward. Base uneven, convex; edge rounded. Moderately formed, moderately well to well finished; matte to medium polish.
Shape very rough, irregular pyramid with rounded base.

Museum Inv. No. None
G (just west of box)
Stone (hematite) sphenondoid weight. Museum Inv. No. None
L. 2.949; max. w. 2.232; max. h. 1.559; mass 30.43 g.
Brownish red of varying shades; speckles of copper oxidation products.
Complete, moderately preserved. Some superficial surface erosion on
top and base surfaces; few minute to medium-size pits here and there; top
and base appreciably chipped.
Top view shape rectangular with three slightly rounded sides, one end
slightly more so and somewhat narrower than other end. Longitudinal
cross section shows barely convex, sloping top and two convex ends, with
shorter one more convex than other. Lateral cross-sectional shape ranges
from slightly irregular hemisphere to truncated circle. Base extends over
entire length and width, flat for part of length, slightly rounded over
remainder, convex over width; edge somewhat sharp. Moderately formed,
moderately well to well finished; matte to medium polish.
Weight essentially bread-loaf shaped.
W 18n. Stone (ilmenite [?]) domed weight.  
Museum Inv. No. None  
Publ. No. W 17 (FN No. 330)  
G (above wooden beam)  
Max. diam. 2.913; min. diam. 2.778; h. 1.855; mass 35.83 g.  
Dark brownish red; iron oxidation products over much of surface.  
Nearly complete, poorly to moderately preserved. One large chip on side  
surface; almost one-half of side surface appreciably chipped, including  
much of top edge and possibly some of base edge.  
Circumference shape apparently originally circular except for one  
straight length. Cross section reveals slightly rounded top and irregular,  
fully rounded sides that join base via faint, crude, rounded bevel. Base  
irregular; edge rounded. Moderately formed, well finished; matte to low  
polish.
W 19n. Stone (hematite ?!) domed weight.

Museum Inv. No. 13-103-5.24
Publ. No. W 18 (FN No. 197) G (near scarab G 37)
Max. diam. 2.735; min. diam. 2.673; h. 1.763; pres. mass 36.19 g (-); cal. mass 36.77 g.
Brownish red; covered with iron oxidation products. Complete, moderately preserved. Entire surface eroded and covered with minute to small pits and exfoliated spots, with one large pit on side surface; one large, shallow chip on base edge, another in central portion of base, and one very large chip on top edge.
Circumference shape very irregularly circular. Cross section reveals flat, slightly sloping top with rounded edge and essentially straight to convex sides. Base slightly concave due to damage; edge rounded. Moderately well formed and finished; matte.
Weight basically thick disk.
Publ. No. W 16 (FN No. 522) G (in hull lump)
L. 3.059; w. 2.907; h. 1.789; pres. mass 27.32 g (-); "est. mass 35.00 g;"
cal. mass 37.04 g.
Black with some white inclusions; thinly scattered iron oxidation products.
Incomplete, poorly preserved. Several large chips and many small ones.
Between one-third and one-half of piece missing and two significant
cracks follow "grain" of stone from broken area to opposite end.
Circumference shape irregularly rounded. Cross section shows slightly
rounded top and rounded side surface. Base uneven, barely convex; edge
somewhat sharp. Moderately well formed, roughly finished or unfinished;
matte.
W 21 n  Stone (hematite) irregular weight.  
Museum Inv. No. None  
Publ. No. W 19 (FN No. 335)  
G (above wooden beam)  
L. 3.5; w. 2.5; mass 42.70 g.  
W 22n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 20 (FN No. 142) G (in sand at entrance to gully)
Max. diam. 2.715; min. diam. 2.574; h. 2.434; mass 43.69 g.
Brownish red; some yellowish cream staining. Complete, moderately
preserved. Appreciable surface erosion; small to medium-size pits and
chips over entire surface with one concentrated area of such on side. One
large shallow gouge on top edge and part of side surface.

Circumference shape irregularly circular. Cross section shows
rounded, slightly sloping top with faint edge, and essentially straight sides
that round into base. Base somewhat uneven but essentially flat; edge
rounded. Moderately to moderately well formed, moderately well
finished; matte.
W 23n. Stone (hematite [?]) sphendonoid weight. Museum Inv. No. 246
Publ. No. W 22 (FN No. 471) G (?)
L. 4.205; w. 2.116; h. 1.923; pres. mass 44.79 g (-); cal. mass 45.31 g.
Darkest brownish red to black. Incomplete, moderately preserved. Many small, thinly exfoliated areas, especially on base. Many small to medium-size chips over all but base, one large chip at intact end, opposite end broken away.

Top view reveals one side an arc except near ends, other side more sharply curved; intact end slightly pointed. Side view shows top curvature notably smooth and symmetrical in relation to weight's length; intact end slightly pointed. End view shows truncated circle. Base covers barely more than half of length and width, gently convex over both axes; edge rounded. Well formed and finished; medium polish.
W 24n. Stone (hematite) sphendonoid weight. Museum Inv. No. None
Publ. No. W 21 (FN No. 331) G (above wooden beam)
L. 4.017; w. 2.326; h. 1.778; pres. mass 45.50 g (-); cal. mass 47.60 g.
Light to dark brownish red; iron oxidation products here and there.
Incomplete, poorly preserved. Surface erosion and medium to large pits
and chips over base and sides; virtually entire top surface chipped away.

Top view shape an elongated, irregular ovoid, one side notably fuller
than other. Side view shows top curvature not preserved, one end more
rounded than other. End view reveals one smoothly rounded side surface;
top and other side not preserved. Base extends over most of length and
width, convex across width, flat along length; edge rounded. Moderately
formed, quality of finish indeterminate; matte.

Weight essentially bread-loaf shaped.
Publ. No. W 23 (FN No. 196) G (near scarab G 37)
Max. diam. 2.820; min. diam. 2.658; h. 2.134; mass 47.70 g.
Dark brownish red; some iron oxidation products. Complete, moderately preserved. Surface erosion and small spots of thin exfoliation cover entire weight; several small to medium-size chips on base and top surfaces.

Circumference shape barely oblong/elliptical. Cross section reveals barely convex, slightly sloping top with distinct edge, and rounded sides. Base slightly convex; edge rounded. Moderately formed, well finished; matte.

Weight shape very barrel-like.
W 26n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 63 (1987 survey) M II (just outside in sand)
Max. diam. 2.769; min. diam. 2.724; h. 2.286; mass 47.78 g.
Dark brownish red with several white inclusions and blue tinge; some iron
oxidation products and black staining. Complete, well preserved. Many
minute pits, few small ones on base, and few small to large ones on top
and side surfaces. Few small chips on side, one shallow, medium-size one
on base.
Circumference shape an irregular circle. Cross section reveals
flattened, slightly inclined top that rounds into rounded sides consisting of
two faint, crude, rounded bevels. Base faintly convex; edge sharp.
Moderately formed, well finished; matte.
Stone (hematite) domed weight.  Museum Inv. No. None
Publ. No. W 24 (FN No. 332)  G (above wooden beam)
L. 2.705; w. 2.345; h. 2.534; mass 47.95 g.
Brownish red; oxidation products on most surfaces. Complete,
moderately preserved. Superficial surface erosion over much of weight.
Few small to medium-size pits, one large one; many small to medium-size
chips, and shallow chipping densely covers ca. one-fourth of one surface.
Shape an irregular cube with faces of unequal dimensions and
somewhat rounded edges, corners, and surfaces. Rectangular base uneven
with roughly rounded edges. Roughly formed and finished; matte.
W 28n. Stone (hematite) sugar-loaf shaped weight. Museum Inv. No. None
Publ. No. W 25 (FN No. 304) Airlift spoil
L. 3.142; max. w. 2.481; h. 2.644; mass 49.11 g.
Brownish red with blue tinge; some dark staining and iron oxidation
products. Complete, moderately preserved. Surface erosion over much
of weight. Several medium-size pits on side surface; small to medium-size
chips on top and base, and one large one on side surface.
Circumference shape an irregular ovoid with truncated side.
Longitudinal cross section shows irregular dome with slightly inclined, flat
length on top and somewhat straight ends. Lateral cross section similar
but part of one side truncated. Base uneven; edge rounded. Poorly
formed and finished; matte.
W 29n. Stone (hematite (?) domed weight. Publ. No. W 26 (FN No. 480) Museum Inv. No. N 92-33 G (below wooden beam) Max. diam. 2.785; min. diam. 2.612; h. 2.385; mass 51.35 g. Brownish red; speckles of iron oxidation products over about one-half of surface area. Complete, moderately well preserved. Minute to small pits scattered over entire weight, several medium-size ones on all surfaces; one large gouge on side surface.

Circumference shape irregularly rounded with three flattened lengths that create vaguely triangular shape. Cross section reveals slightly rounded top with rounded edge and rather gentle, convex sides. Base slightly convex; edge rounded. Moderately formed, well finished; matte to medium polish.
W 30n.  Stone (hematite) domed weight.  
Museum Inv. No. None  
Publ. No. W 27 (FN No. 90)  
M I (old G 25)  
Max. diam. 3.063; min. diam. 2.782; h. 2.820; mass 53.61 g.  
Brownish red; thin, widespread deposit of iron oxidation products.  
Complete, excellently preserved. Several medium-size to large pits.  
Circumference shape irregularly ovoid. Cross-sectional shape irregularly domed. Base uneven, faintly convex; edge rounded. Poorly or roughly formed, unfinished; matte.
W 31n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. 28 (FN No. 129) M II (old S 25)
Max. diam. 2.898; min. diam. 2.872; h. 2.305; mass 53.90 g.
Brownish red; dark brown to black staining over ca. one-half of surface
area. Complete, well preserved. Some superficial surface erosion and
minute to small pitting in stained area; a few small pits on top and base
surfaces.

Circumference shape nearly a circle. Cross section shows uneven,
slightly convex top and rounded edge in form of faint, rounded bevel, and
convex sides. Base somewhat sloping, slightly convex; edge rounded.
Moderately well formed, well finished; matte to medium polish.
W 32n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 29 (FN No. 333) G (above wooden beam)
Max. diam. 3.163; min. diam. 3.011; h. 2.330; pres. mass 55.79 g (-); cal.
mass 57.45 g.
Light brownish red, darkest brown to black in broken and exfoliated areas;
some iron oxidation products. Incomplete, poorly preserved. Appreciable
pitting on base and side surfaces, including several large pits on side;
several medium-size to large exfoliated spots and larger areas. One piece
of possibly large, but indeterminate size broken off of one end.

Circumference shape resembles irregular ovoid, now truncated where
broken. Longitudinal cross section reveals rounded, sloping top merging
to one convex end that rounds into base, other end irregular due to
breakage. Lateral cross section shows partly rounded, steeply sloping,
even top and rounded sides. Base essentially flat over long axis, slightly
convex over short; edge rounded. Moderately formed, moderately well
finished; matte.
Stone (hematite) sphendonoid weight.

Museum Inv. No. N 89-3
Publ. No. W 30 (FN No. 475)  
G (in hull lump)
L. 3.424; w. 2.520; h. 2.387; pres. mass 57.20 g (-); cal. mass 58.18 g.

Dark brownish red; one side covered with iron oxidation products. Nearly complete, moderately preserved. Some small to medium-size pits here and there, one very large one on one side surface. Small to medium-size chips here and there, one large, shallow one on each large side surface, and ca. one-third of one large side surface chipped away.

Top view shows irregular rectangle with rounded corners, one especially so, sides and one end convex, the other end more rounded. Side view reveals convex ends and irregular top and base. End view shape an irregular ovoid with flattened or truncated top and irregular bottom. No well-defined base. Roughly formed and finished; matte.
W 34n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 31 (FN No. 326) G (above wooden beam)
Max. diam. 2.805; min. diam. 2.744; h. 2.578; mass 58.79 g.
Brownish red; much of surface stained dark brown to black. Complete,
moderately well preserved. Surface erosion on base; some small to
medium-size pits and one large one on side surface; shallow small to large
chips on all surfaces, especially sides.
Circumference shape irregularly circular. Cross section shows barely
convex, somewhat uneven, slightly sloping top joined to uneven, convex
sides by faint, rounded bevel. Base uneven and somewhat concave; edge
rounded. Moderately formed and finished; matte.
Stone (magnetite [?]) sphendonoid weight. Museum Inv. No. None
Publ. No. W 32 (FN No. 327) G (above wooden beam)
L. 5.383; w. 2.334; h. 2.136; mass 63.41 g.

Dark gray; iron oxidation products here and there. Complete, moderately preserved. Surface erosion over entire weight; medium-size chips here and there and several possible large chips on top, sides, and base.

In top view sides crude and irregular; one end appears truncated, the other rounded. Side view shows top has exaggerated central hump with slight concavities near both ends; one end rounded, other nearly straight and vertical. End view shape roughly rectangular with rounded corners and sides. Irregular and uneven base extends over nearly entire length and width; edge irregular. Poorly formed and finished; matte.

Publication suggests piece may not have been finished, but its shape not consistent with that of unfinished sphendonoid weight, as all surfaces seem too planar.
W 36n. Stone (hematite) sphendonoid weight. Museum Inv. No. None
Publ. No. W 34 (FN No. 314A) G (with bun ingot G 106)
L. 4.408; w. 2.269; h. 2.149; mass 65.29 g.
Dark to light brownish red; iron oxidation products at one end. Complete,
well preserved. Superficial surface erosion here and there. Minute pitting
and some medium-size pits here and there; large natural flaw or concavity
on top at one end somewhat eroded.
Top view shows two long, slightly curved sides, and rounded ends, one
end slightly irregular. Side view reveals approximately two-thirds of top
curvature fairly flat with faint, rounded bevel reaching to higher end;
remainder of top angles down to opposite end. Ends faintly rounded,
 principalmente straight and vertical. End view shape irregularly rounded. Base
extends over nearly entire length and width, convex across both axes; edge
rounded. Well formed and finished; matte to medium polish.
W 37n. Stone (hematite [?]) sphendonoid weight. Museum Inv. No. None
Publ. No. W 35 (FN No. 183) M II (just outside in sand)
L. 4.121; w. 2.804; h. 2.277; mass 66.62 g.
Black, but it is probably a uniform stain, as spots of red are visible here
and there, with several white inclusions seemingly exposed by pitting or
chips. Complete, poorly to moderately preserved. Except for most of
base, virtually entire surface pitted and chipped, with several medium-size
and large chips.
Top view shape approximates irregular ellipse with uneven sides. Side
view shows that top curves harder to one end than to other, both ends
convex. End view shape truncated circle irregularly rounded with several
large flattened spots. Uneven, slightly convex base covers most of length
and width; edge rounded. Moderately formed, moderately well finished;
matte to medium polish.
Stone (hematite) sphendonoid weight.

Museum Inv. No. None
Publ. No. W 36 (FN No. 91)
L. 5.322; w. 3.029; h. 1.862; mass 67.41 g.

Dark brownish red to dark brown. Completeness and degree of preservation indeterminate. Surface somewhat eroded and entirely chipped and broken.

Top view shows one irregular side curvature, the opposite one irregularly straight, both ends roughly rounded with large chunk missing from one. Side view shape rough and irregularly convex. End view shape entirely irregular. Quality of form and finish indeterminate; matte.

This piece displays no smoothly worked surfaces whatsoever.
Stone (hematite) sphendonoid weight.  
Museum Inv. No. None  
PUBL. NO. W 33 (FN NO. 217)  
G (south of box)  
L. 4.374; w. 2.874; h. 2.512; pres. mass 63.63 g (-); cal. mass 68.97 g.  
Exposed subsurface various shades of orange red to bluish red; most of  
original surface stained with copper oxidation products, remainder is dark  
to light brown or pinkish. Incomplete, poorly preserved. Surface erosion  
and exfoliation to varying degrees over most of surface especially bad on  
one side, extending to one end that is broken away.  
In the top view, intact side slightly angular, intact end truncated. Side  
view shows top fully rounded in central portion and toward broken end,  
more linear to truncated end, which is straight and vertical; a bevel joins  
that end to base. End view shape a truncated circle. Flat base extends  
over most of length and width; edge fairly sharp. Well formed and  
finished; matte.
W 40n. Stone (hematite) sphendonoid weight. Publ. No. W 38 (FN No. 325)
L. 4.393; w. 2.515; h. 2.058; mass 69.12 g.
Presumably brownish red; virtually entirely covered with iron oxidation products. Complete, moderately preserved. Appreciable surface erosion; small to medium-size pits here and there; several medium to large chips.
Top view shape rectangular with slightly convex sides and ends, and rounded corners. Side view shows convex ends, top and base slope slightly toward one end. Laterial cross sections range from almost elliptical to ovoid with slightly truncated top. No well-defined base. Moderately formed, moderately well finished; matte.

Museum Inv. No. None
G (above wooden beam)
W 41n. Stone (sandstone) domed weight. Museum Inv. No. None
Publ. No. W 41 (FN No. 461) S (under ingot S 17)
Max. diam. 4.153; min. diam. 3.733; h. 3.389; mass 73.22 g.
Grayish tan; some copper oxidation products. Complete but excessive
chipping, moderately preserved. Appreciable number of medium-size
to large chips around side and base surfaces. Two rather large gouges on
one side surface, one deeper than the other, meet at about 90 degrees and
appear to comprise more distinct lower half of crude X slightly inclined to
base.

Circumference shape consists of ca. one-half roughly rounded, other
half of two roughly straight sides meeting at ca. 90 degrees. Cross section
reveals slightly sloping, faintly convex top rounding into nearly straight,
irregular sides. Base uneven but essentially flat; edge rounded. Poorly to
moderately formed, poorly finished; matte.

What may be faint X on one side surface so poorly preserved
and/or executed that it must be most cautiously regarded as mark, and
may be the product of coincidental damage.
W 42n. Stone (magnetite) domed weight. Museum Inv. No. None
Publ. No. W 39 (FN No. 412) G (below wooden beam)
Max. diam. 3.689; min. diam. 3.490; h. 2.262; mass 75.67 g.
Dark brownish red. Nearly complete, poorly to moderately preserved.
Surface erosion on base and much of side surface; entire weight chipped,
pitted, and exfoliated to varying degrees, with many large pits and chips.
Circumference shape very irregularly circular. Cross section reveals
gently rounded top merging with irregular, nearly straight to convex sides.
Base uneven but essentially flat; edge rounded. Poorly formed and
finished; matte.
Stone (magnetite [?]) domed weight.

Publ. No. W 40 (FN No. 521)
L. 3.564; w. 2.806; h. 2.798; mass 76.63 g.

Black; dusted with iron oxidation products. Complete, well to very well preserved. Minute to medium-size pits over most of surface, with a few large ones.

Circumference shape and longitudinal cross-sectional shape roughly elliptical. Lateral cross section irregular truncated circle. Uneven top flattened and inclined toward one end. No well-defined base. Roughly formed, perhaps unfinished; matte.
W 44n. Metal (copper) irregular weight. Museum Inv. No. None
Publ. No. W 37 (FN No. 498) Not mentioned
L. 3.506; w. 2.722; h. 2.060; pres. mass 68.54 g (-); est. mass 82.88 g.
Dark gray to black; covered with copper oxidation products.
Complete (?), moderately well preserved. Uniform surface erosion over
entire weight; some minute to small pits and three large ones.
“Top” view shape roughly triangular with irregular hypotenuse and
vertices. Side view shows convex and uneven top, with one end rounded
and other irregular. End view shape a rough trapezoid, with “top” and
“base” essentially parallel. “Base” over nearly entire surface is uneven but
essentially flat; edge rounded. Quality of form and finish indeterminate;
matte.

Probably fragment of cooper ingots rather weight piece.
Stone (hematite) domed weight.  
Museum Inv. No. None  
Publ. No. W 42 (FN No. 311) G (with bun ingot G 106)  
Max. diam. 3.542; min. diam. 3.433; h. 2.823; mass 85.97 g.  
Brownish red with some blue tinge; dark staining over much of weight, 
black in exfoliated areas, and some iron oxidation products. Complete, 
moderately preserved. Surface erosion on base and much of side surface. 
Some areas densely covered with minute to small pits, one medium-size 
one near top, two on base edge; patch of thin exfoliation extends from 
near top down onto base.  
Circumference shape irregularly circular with three flattened lengths.  
Cross-sectional shape an irregular, asymmetrical dome. Base flat with 
rounded edge. Moderately formed, moderately well finished; matte.
W 46n. Stone (hematite (?) domed weight. Museum Inv. No. None
Publ. No. W 43 (FN No. 466) G
Max. diam. 3.623; min. diam. 3.514; h. 2.533; mass 91.05 g.
Light brownish red; extensively stained, especially with notably yellowish iron oxidation products. Complete, moderately preserved. Entire surface appreciably pitted; some exfoliation on base.
Circumference shape an irregular circle. Cross section reveals faintly concave top with distinct edge merging via crude, rounded bevel into smoothly rounded sides. Base flat; edge rounded. Moderately formed and finished; matte.
W 47n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 44 (FN No. 181) M II (just outside in sand)
Max. diam. 3.506; min. diam. 3.389; h. 3.164; mass 93.11 g.
Dark brownish red; extensive dark staining. Complete, well to very well
preserved. Uniform superficial surface erosion; appreciable minute pitting
over entire surface and few small to medium-size pits on top.
Circumference shape irregularly circular. Cross section reveals
rounded top and fully rounded sides. Base slightly convex; edge rounded.
Moderately well formed, well finished; matte.
W 48n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 45 (FN No. 328) G (above wooden beam)
Max. diam. 3.865; min. diam. 3.733; h. 2.869; mass 99.31 g.
Dark brownish red; copper and iron oxidation products over much of
surface. Complete, well preserved. Few small to medium-size pits here
and there; several gouges and large chips.

Circumference shape a notably irregular circle. Cross-sectional shape
ranges from elliptical to irregularly lentoid/biconvex. No well-defined
base. Moderately formed, well finished; matte.
Metal (copper) oblong weight.

Publ. No. W 46 (FN No. 169)  
Museum Inv. No. None  
M II (old S 23)

L. 6.078; w. 2.182; h. 2.182; pres. mass 108.15 g (-); est. mass 141.1 g.

Black; most of surface covered with copper oxidation products. Complete (?) not preserved. Uniform surface erosion over entire weight; many small to medium-size pits, five large ones; large part of base edge around one end chipped away.

Top view shape oblong with irregular, slightly rounded sides and rounded ends, one end irregular due to damage. Side view shows top uneven and barely concave with rounded edges, opposite surface irregular. Intact end convex and angled slightly outward, other irregular due to damage. End view shape roughly hexagonal with rounded top. Base uneven; edge mostly rounded. Quality of form and finish indeterminate; matte.

Probably fragment of copper ingot ("ear" section [?]) rather than weight piece.
W 50n. Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 47 (FN No. ?) Probably from hull lump
Max. diam. 3.840; min. diam. 3.770; h. 3.610; mass 146.23 g.
Dark brownish red; extensive black staining. Complete, very well
preserved. Some superficial surface erosion; one medium-size chip on
base and large one on side surface at base edge.

Circumference shape irregularly round. Cross section shows nearly
flat, sloping top and fully rounded sides. Base somewhat uneven,
essentially flat, edge rounded. Moderately formed, well finished; low to
medium polish.
Stone (hematite) sphenoidal weight.
Publ. No. W 48 (FN No. 334)
L. 6.366; max. w. 3.421; h. 2.611; mass 175.80 g.
Brownish red to dark brownish red; copper oxidation products on one end. Nearly complete (?), moderately preserved. Surface may be uniformly eroded, or possibly just unfinished/unworked. A few small to medium-size pits; many small to medium-size chips and one very large one in the form of a missing corner on top; large diagonal concavity across width of base may be result of extensive chipping and other damage.

Top view shape very irregularly rectangular with rounded ends and somewhat concave sides. Longitudinal cross section shows top uneven and rounded, ends essentially straight and angled slightly inward. Lateral cross section shows slightly uneven and convex top and uneven, essentially straight sides that are sometimes nearly vertical and sometimes angled inward. Base very rough and uneven with large, crude, diagonal concavity across width. Roughly formed and finished; matte.
W 52n. Stone (hematite ?) domed weight. Museum Inv. No. None
Publ. No. W 49 (FN No. 131) M II (old S 31)
Max. diam. 4.530; min. diam. 4.306; h. 3.651; mass 184.93 g.
Dark brownish red; extensive iron oxidation products on side and base
surfaces. Complete, well preserved. Appreciable surface erosion over
most of weight; significant number of small to medium-size pits in same
areas, and one large pit on base edge.

Circumference shape irregularly circular. Cross section shows uneven,
sloping, irregularly rounded top with rounded edge merging into rounded
sides. Base slightly convex; edge rounded. Moderately formed, well
finished; medium polish.
W 53n.  Stone (hematite) domed weight.  Museum Inv. No. None
Publ. No. W 50 (FN No. 128)  M II (old S 24)
Max. diam. 4.426; min. diam. 4.273; h. 3.325; mass 187.56 g.
Darkest brownish red. Complete, very well preserved. Minor to small
pits over most of surface, a few of medium size on side surface; one large
but shallow chip on base.

Circumference shape irregularly circular. Cross section reveals faintly
convex, slightly sloping top with rounded edge merging into rounded sides
via faint, crude, rounded bevel more evident in some areas than in others.
Base faintly convex; edge rounded. Moderately formed, very well
finished; medium to high polish.
Stone (hematite or ilmenite) domed weight. Museum Inv. No. None
Publ. No. W 51 (FN No. 127[?]) M IV (old S 22)
Max. diam. 4.469; min. diam. 4.421; h. 3.760; mass 193.06 g.
Brown to brownish red. Complete, well preserved. Uniform superficial
surface erosion. Most of surface covered with minute to small pits,
several of medium size, and one large one on side near top; one large chip
or gouge on base edge.

Circumference shape irregularly circular. Cross section shows barely
convex top with slight depression rounding smoothly into sides that round
sharply into base. Base somewhat irregular, slightly concave; edge
somewhat sharp. Moderately formed, moderately well finished; matte.
W 55n. Stone (hematite) sphenodonoid weight. Museum Inv. No. 13-106-1.2
Publ. No. W 52 (FN No. 96)
L. 7.327; w. 3.252; h. 2.893; mass 202.71 g.
Dark brownish red with blue tinge, some white inclusions; copper oxidation products here and there. Nearly complete, poorly preserved. Possibly uniform surface erosion; a few small to medium-size pits; top and base, exhibit large chipped areas.
Top view shape very crude rectangle with rounded corners, convex ends, and uneven sides, one angled inward to one end. Longitudinal cross section shows uneven, convex top slightly angled at edges and convex ends. Lateral cross-sectional shape ovoid/elliptical. Base very uneven due to damage, probably originally straight or slightly convex. Roughly formed and finished, possibly unfinished; matte.
Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 54 (FN No. 3??) G (below wooden beam)
Max. diam 4.867; min. diam. 4.538; h. 4.422; pres. mass 240.64 g (-); cal.
mass 246.29 g.
Brownish red; almost entirely covered with iron and copper oxidation
products. Incomplete, poorly preserved. Rather uniform surface erosion.
Entire surface covered with minute pits and exfoliated spots; many small
to medium-size chips and exfoliated areas; three large chipped and gouged
areas on side surface. Large depression on top seems not to be damage
but part of original form.
Circumference nearly circular except ca. one-fourth flattened. Cross
section shows uneven top with large depression that rounds smoothly into
sides that round sharply into the base. Base somewhat uneven; slightly
convex. Moderately formed, finish indeterminate; matte.
Stone (hematite) domed weight. Museum Inv. No. None
Publ. No. W 55 (FN No. 132) M II (just outside in sand)
Max. diam. 5.013; min. diam. 4.926; h. 3.854; mass 278.07 g.
Dark brownish red. Complete, very well preserved. Minute to small pits
over entire surface, particularly dense over base and part of side surface,
one medium-size pit on side, several around base edge.

Circumference shape slightly irregular circle. Cross section shows
faintly rounded, sloping top that merges with rounded sides. Base barely
convex; edge rounded. Moderately well formed, very well finished;
medium polish.
Stone (hematite) sphendonoid weight. Museum Inv. No. None
Publ. No. W 67 (1987 survey) Unknown
L. 5.859; w. 4.293; h. 3.818; mass 281.83 g.
Dark to light brownish red. Complete, well preserved. Some superficial
surface erosion over side surface and one end, the other end slightly more
eroded. Many small to large pits on side surface; several small chips on
one end and few on opposite end, along with large one.

Top view shape rectangle with rounded corners and convex sides, one
end flatter and slightly wider than other, more rounded end. Side view
shape nearly elliptical, though one end less rounded than other. End view
shape essentially elliptical to ovoid. No well-defined base. Moderately
well formed, well finished; matte to low polish.
W 59n. Stone (ilmenite) domed weight.
Museum Inv. No. None
Publ. No. W 53 (FN No. 133) M II (old S 30)
Max. diam. 5.032; min. diam. 4.935; h. 4.285; mass 282.01 g.
Brownish red with cream to tan eroded impurities; large black stain over
one-half of weight. Complete, well preserved.
Circumference shape slightly irregular circle. Cross section exhibits
gently convex top with crude, rounded bevel more evident in some areas
than in others, and rounded sides that angle inward somewhat to base.
Base slightly convex; edge fairly sharp. Moderately formed, well finished;
matte to medium polish.
Stone (hematite or ilmenite) sphendonoid weight. Museum Inv. No. None
Publ. No. W 56 (FN No. 141) G (in sand at entrance to gully)
L. 7.216; w. 3.953; h. 3.645; mass 283.59 g.
Dark brownish red to dark gray, though latter could be staining.
Complete, moderately well preserved. Surface erosion over entire weight;
several small chips on top and on base near one end.

Top view shows one side an arc, other slightly flatter over central
portion, except for tighter curvatures near ends; ends are truncated and
somewhat rounded. In side view, top an arc except near ends, one of
which is straight and vertical, other slightly rounded; bevels between ends
and base very rounded. End view shape verges on faint rectangle with
smoothly rounded sides and corners. Base extends over most of length
and width, convex across both axes; edge rounded. Moderately well to
well formed and finished; matte.
Stone (hematite) domed weight.

Museum Inv. No. None
Publ. No. W 57 (FN No. 130)
Max. diam. 5.736; min. diam. 5.527; h. 5.715; mass 456.91 g.
Brownish red; large areas are stained black or display copper oxidation products. Complete, moderately well preserved. Some superficial surface erosion; more than one-half of surface appreciably pitted with minute to large pits.

Circumference shape slightly irregular circle. Cross section shows rounded, slightly uneven, sloping top merging with slightly rounded sides via faint, crude, rounded bevel more evident in some areas than in others. Base slightly convex; edge moderately sharp. Moderately well formed and finished; matte to medium polish.
Stone (hematite) sphendonoid weight.  
Museum Inv. No. N 89-27
Publ. No. W 59 (FN No. 390)
L. 7.782; max w. 4.864; min. w. 4.142; h. 3.859; mass 460.75 g.
Brownish red; patches of iron oxidation products. Complete, moderately preserved. Superficial surface erosion over most of weight; small to large pits here and there; several large chips on ends; most of surface exfoliated.

Top view shape roughly trapezoidal with convex sides, one end rounded, the opposite end essentially straight or faintly convex and narrower than other. Side view shape similar, with higher end corresponding to narrower end in top view. End view shape approximately elliptical to nearly square with rounded corners and convex sides. Base essentially flat; edges rounded. Moderately well to well formed and finished; matte.

The general shape resembles that of KW 753, which is proportionally shorter, however, and cruder in its proportions as well.
W 63n. Stone (hematite) sphendonoid weight. Museum Inv. No. None
Publ. No. W 58 (FN No. 310) G (with bun ingot G 106)
L. 9.259; w. 4.343; h. 3.915; mass 462.55 g.
Dark brownish red; scattered iron and copper oxidation products.
Nearly complete, poorly preserved. Some surface erosion; several large
pits; surface possibly nearly entirely exfoliated; large portions of surface
chipped or gouged away.
Top view shape oblong with rough, irregular sides; one rough, rounded
end and one irregular end. Longitudinal cross section shows one rough,
rounded end and convex top and base that become angular and meet at
blunt end. Lateral cross-sectional shape roughly elliptical. No well-
defined base. Quality of form and finish indeterminate; matte.
Stone (hematite) sphendonoid weight. Museum Inv. No. 13-106-1.0
Publ. No. W 60 (FN No. 64)
L. 9.610; w. 4.884; h. 4.423; mass 499.46 g.
Dark brownish red with blue tinge. Complete, well preserved.
Superficial surface erosion and minute through small pits over virtually entire weight; several large pits on one side; some medium-size chips on underside near one end.

In top view, one side more angular than other and ends truncated, one more rounded than the other. Side view reveals top curvature flattens near center, and angles in nearly straight lines to ends that are faintly convex; bevels between ends and base faintly convex. End view shows truncated circle with flattened top and irregularly rounded sides. Base extends over most of length and width, and slightly convex across both axes; edge rounded to fairly sharp. Moderately well formed, well finished; matte to low polish.
Max. diam. 10.173; min. diam. 10.095; h. 5.135; mass 872.10 g.
Tan with light green tinge. Complete, excellently preserved. One shallow,
somewhat narrow, medium-size gouge on top surface with larger
possibly gouged area of about same depth nearby.

Circumference shape a slightly irregular circle. Cross section shows
uneven, rounded top with several shallow concavities or depressions, and
rounded edge that appears to be worn in one area; sides slightly convex to
essentially straight and vertical. Base essentially flat, but uneven in some
areas that appear to be worn, particularly one portion of edge that takes
the form of bevel. Appears to have been well formed and finished; matte.

Surface very friable and would seem to make this piece ill-suited to use
as weight, unless this surface condition is result of extended submersion.
VITA

Cemalettin M. Pulak, born in Izmir, Turkey on 29 December 1951, received his B.S. and M.S. degrees in mechanical engineering from Bosphorus University, Istanbul, in 1974 and 1977, respectively. Pulak joined the Institute of Nautical Archaeology (INA) as a volunteer each summer in Turkey while completing his graduate degree in engineering and later, while serving in the Turkish Navy. Invited to study nautical archaeology by Professor George F. Bass, he entered the Graduate College of Texas A&M University, Department of Anthropology in 1980, and received his M.A. degree in anthropology with a specialization in nautical archaeology in 1987.

Pulak was appointed a research associate with INA in 1981 and has participated in many underwater projects in Turkey and Jamaica. He directed the excavation of a 3rd-century B.C.E. Hellenistic period shipwreck in 1979 and 1980, and a 16th-century Ottoman shipwreck in 1982 and 1983, in Turkey. Pulak also has been directing INA’s annual shipwreck surveys along the Turkish coast since 1983. After 11 excavation campaigns, he has recently completed his field work on a Late Bronze Age shipwreck in Turkey, which he has been directing since 1986, and is currently involved with researching and publishing material from the site.

As INA’s vice-president, Pulak spends half of each year in Turkey engaged in field work. He also administers INA’s Turkish facilities in Bodrum, which he has been directing since 1993.

His permanent address is:

Institute of Nautical Archaeology
P.O. Drawer HG
College Station, TX 77841-5137