# Protoapennine vs. Subapennine: Mathematical Distinction between Two Ceramics Phases

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*The excavation of the Early Bronze Age village of Tufariello, Buccino, in Italy forced the recognition of a problem crucial to the understanding of the Bronze Age sequences in the Italian peninsula. At this site, fine ceramic ware exactly fit the description of such ware known from Subapennine, Late Bronze Age sites. The Tufariello site, however, is firmly set in an Early Bronze Age, Protoapennine tradition, thus demonstrating convincingly that the beginning and final moments of the Apennine ceramic tradition may visually be identical.*

*Since the validity of both phases has been established, it is imperative to develop a means of identifying the respective ceramics. That they must in some manner differ is suggested by the time span separating their manufacture (perhaps as long as 800 years), and a differentiation based on mathematical analysis of their primary measurements is discussed here.*

**Description of the Problem and the Data**

The Middle Bronze Age within the broad limits of 1800-1200 B.C. of the central and southern peninsula of Italy is known as the Apennine culture.[1] This great Middle Bronze Age culture, known primarily through cave deposits, was an outgrowth of the local Copper Age groups, and has been characterized as a pastoral, stock-breeding society.[2] Relatively few bronze daggers, stone battle-axes, and arrowheads have been recovered. Chief among the remains, however, are the ceramics: the finer ware was hand-made, dark in color, and burnished to a luster, improving both its appearance and its ability to hold liquids (by rendering it impervious). While there is a wide variety of shapes, the *capeduncola* (a one-handled cup or bowl, FIG. 1) predominates. The most striking feature of the ceramics is perhaps the incised and excised decoration covering a large part of the bodies of the fine-ware vessels.

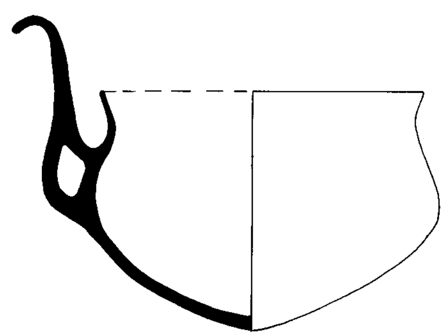

Figure 1. Typical Protoapennine *capeduncola* (cup).

The existence of a later phase of this culture, the Subapennine, has been acknowledged for some time, but only recently has the existence of its counterpart, an earlier phase, the Protoapennine, been verified.[3] A confusion

1. Susan Lukesh wishes to thank the personnel from the various museums, both directors and staff, without whose assistance the raw data for this study could not have been gathered. Special appreciation is extended to Madelaine Cavalier for her graciousness on the island of Lipari. The funding for this research, carried out in the summer of 1976, was supplied in large part by a grant from the Penrose Fund of the American Philosophical Society.

2. Primary references for the Apennine Culture include D. H. Trump, *Central and Southern Italy before Rome* (London 1966), as well as his earlier, "The Apennine Culture of Italy," *ProcPS* XXIV (1958); S. M. Puglisi, *La Civilta appenninica* (Florence 1959). References since these publications can be found in M. A. Fuggazola Delpino, *Testimonianze di Cultura appenninica nel Lazio* (Florence 1976).

3. The term Subapennine was introduced by Puglisi, op. cit. (in note 2), passim., and given chronological significance by R. Peroni, "Per una definizione dell'aspetto cultural 'subappenninico'

between the fine ceramics of the Subapennine and Protoapennine phases developed from, and lies today in, their remarkable similarity to one another: the ware, called *impasto* in Italian, is hand-made and highly burnished, and exhibits the wide variety of shapes long known from the full Apennine period, but lacks the characteristic incised and excised decoration. The excavation of the Early Bronze Age village of Tufariello, Buccino, brought into clear focus this problem of undecorated fine wares of the Italian Bronze Age.[4] From Tufariello, the primary remains were ceramic, including a class of fine ware, undecorated and remarkably undifferentiated from Subapennine pottery known to date. But the site itself is firmly set into an Early Bronze Age context: relatively, because of stratigraphic evidence above and below the village, and absolutely, based on thermoluminescence dating.[5] Previously, ceramic remains from a few sites that were themselves accepted as early, were considered Subapennine (that is, later), at times necessitating fanciful explanations of their deposition.[6]

With the excavation of Tufariello, the problems presented by the strong similarities between the ceramics of these two phases, which are chronologically quite distinct, could no longer be ignored. The acceptance of the validity of both phases raised the primary question of how the material could be differentiated. The lengthy period of time (perhaps as long as 800 years) separating the phases must in some manner be reflected in the material, and, indeed, three years of close study of this material has made it possible to distinguish the ceramics of the two periods. But it is important to develop an objective means both of demonstrating and communicating this differentiation. The following discussion relates one attempt to isolate these differences.

Sites from which to select *capeduncolae* (cups) for this study were chosen on the basis of non-ambiguous assignment to either Protoapennine or Subapennine: stratigraphic situation is the best indicator, but other evidence leading to establishment of one date or the other, and its universal acceptance, was also considered. Vessels from sites with neither stratigraphic evidence nor clear signs indicating date of deposition (artifactual and other remains) are not considered: as a result, chance finds are eliminated as well as small deposits with no other evidence. A secondary consideration had to be, of course, the availability of these vessels for measurement. Unfortunately, because of the temporary closing of the prehistoric section of the Taranto Museum, a major body of Protoapennine material could not be studied. Nonetheless, the sample of 100 cups (45 Protoapennine, 55 Subapennine), with five measurements for nearly all (height, neck height, maximum or shoulder diameter, rim diameter, and neck diameter), was large enough, we felt, for these preliminary analyses. Table 1 lists the data used in the analyses, indicating site of origin,

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come fase crononologica e se stante," *MAL* 9 (1959). Puglisi was also responsible for introducing the term Protoapennine, "Sulla facies protoappenninica in Italia," *Atti del Congresso Internazionale della Scienze Preistoriche e Protostoriche*, Rome, 1962.

4. R. R. Holloway and colleagues, "Buccino: The Early Bronze Age Village of Tufariello," *JFA* 2 (1975) 11-81. Puglisi has acknowledged the similarity, recognising the phenomenon of the convergence of general characteristics manifest in both embryonic and final stages of an evolution, S. M. Puglisi, "L'Eta del Bronzo nella Daunia (Relazione generale)," *Civilta Preistoriche e Protostoriche della Daunia, Atti del Colloquio Internazionale di Preistoria e Protostoria della Daunia, Foggia, 24-29 Aprile 1975* (Florence 1975) 225-34, pl. 54-62.

5. Holloway, op. cit. (in note 4) 12-19.

6. See for example the arguments on the site of Altamura in S. S. Lukesh, "Tufariello (Buccino): Preliminary Reconsiderations of Bronze Age Sequences in the South Italian Context," *Rivista di Scienza Preistoria* (forthcoming).

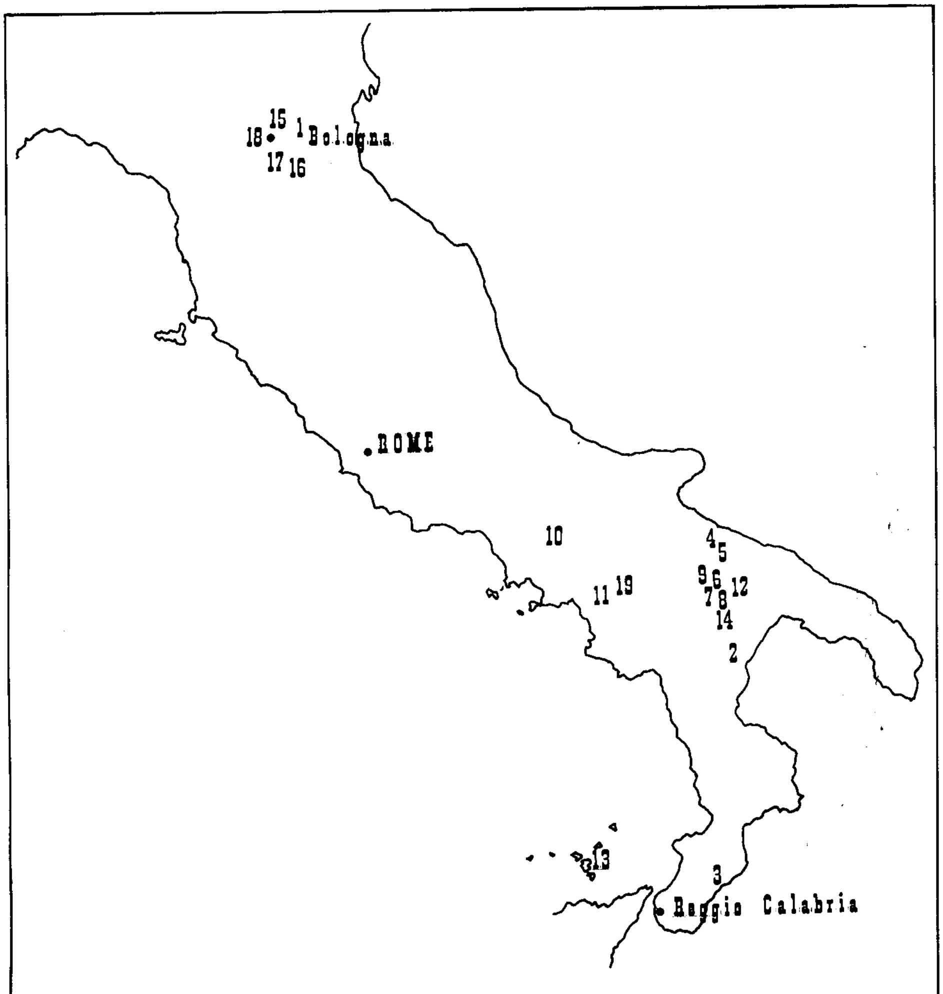


Figure 2. Map of Italy showing sites from which cups were selected. Numbers correspond to site numbers in Table 1.

measurements, and, in the last column, assignment either to Protoapennine (2) or Subapennine (4).

The map (FIG. 2) illustrates the geographical positioning of these sites. It is clear from the map that the northernmost examples of Protoapennine are from La Starza, while Subapennine remains have been found as far north as Bologna. This is understandable considering the expanding population of the Late Bronze Age.

### Mathematical Methods and Results

Mathematics offers a rich source of useful, objective tools for exploratory data analysis.[7] As a first step in exploration, one needs literally to look at the data. For the particular problem of discovering both underlying similarities and differences between the cups of these two periods, we looked at the data in two simple forms—histograms and scatter diagrams. After visual consideration of the histograms and scatter diagrams, the more complex and less visual mathematical method of multiple regression was used to obtain a direct method for distinguishing between Protoapennine and Subapennine cups.

The simplest mathematical procedure employed yielded histograms of fre-

7. For a modern approach to this field, see J. W. Tukey, *Exploratory Data Analysis* (Reading, Massachusetts, 1977).

Table 1. Raw data*

| | SITE | No. | Museum No. | DIAMETERS Rim | Neck | Shoulder | Base | HEIGHTS Total | Neck | Period** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | G. Del Farneto | 76BO005 | 40928 | 11.1 | 10.0 | 10.3 | 5.2 | 5.5 | 2.5 | 4 |
| | G. Del Farneto | 76BO006 | 2039 | 9.5 | 9.2 | 9.8 | 1.2 | 4.8 | 2.0 | 4 |
| | G. Del Farneto | 76BO007 | 2068 | 20.8 | 20.9 | 22.0 | 6.5 | 9.5 | 3.8 | 4 |
| | G. Del Farneto | 76BO008 | 1962 | 8.0 | 00.0 | 9.0 | 00.0 | 6.8 | 4.0 | 4 |
| | G. Del Farneto | 76BO010 | 2121 | 26.0 | 00.0 | 25.0 | 7.3 | 8.3 | 2.0 | 4 |
| | G. Del Farneto | 76BO011 | 2135 | 19.5 | 18.2 | 19.5 | 8.5 | 8.8 | 2.7 | 4 |
| | G. Del Farneto | 76BO012 | 2108 | 15.5 | 15.5 | 18.8 | 7.0 | 9.8 | 3.2 | 4 |
| | G. Del Farneto | 76BO013 | 2066 | 11.7 | 11.1 | 11.5 | 00.0 | 3.8 | 1.4 | 4 |
| | G. Del Farneto | 76BO014 | 1999 | 10.8 | 10.7 | 10.8 | 00.0 | 3.5 | 1.7 | 4 |
| | G. Del Farneto | 76BO015 | 1980 | 15.0 | 16.1 | 16.4 | 7.5 | 11.8 | 3.5 | 4 |
| | G. Del Farneto | 76BO016 | 2067 | 18.5 | 16.4 | 18.0 | 7.0 | 10.5 | 4.8 | 4 |
| 2. | S. Angelo II | 76RC001 | | 11.0 | 00.0 | 14.0 | 3.0 | 11.0 | 2.0 | 4 |
| | S. Angelo II | 76RC002 | | 11.0 | 00.0 | 12.5 | 7.3 | 10.5 | 2.4 | 4 |
| | S. Angelo II | 76RC003 | | 10.5 | 0.0 | 12.1 | 3.5 | 10.5 | 2.5 | 4 |
| | S. Angelo II | 76RC004 | | 10.0 | 00.0 | 18.0 | 00.0 | 15.3 | 99.9 | 4 |
| 3. | S. Onorio D. Roc. | 76RC005 | | 11.0 | 10.1 | 12.0 | 00.0 | 4.3 | 3.0 | 2 |
| | S. Onorio D. Roc. | 76RC006 | | 15.0 | 14.0 | 17.0 | 7.0 | 5.5 | 2.0 | 2 |
| | S. Onorio D. Roc. | 76RC007 | | 8.5 | 8.2 | 9.4 | 00.0 | 3.8 | 2.5 | 2 |
| 4. | Bisceglie | 76BA001 | | 19.0 | 19.0 | 20.0 | 00.0 | 14.3 | 5.0 | 2 |
| | Bisceglie | 76BA002 | 5180 | 10.1 | 9.8 | 11.8 | 3.4 | 5.3 | 1.7 | 2 |
| | Bisceglie | 76BA003 | 5178 | 11.5 | 10.5 | 9.9 | 4.4 | 3.3 | 2.0 | 2 |
| | Bisceglie | 76BA004 | 5177 | 9.0 | 8.4 | 8.4 | 0.0 | 3.6 | 1.5 | 2 |
| 5. | Terlizzi | 76BA007 | 5506 | 11.0 | 8.9 | 9.5 | 2.8 | 5.8 | 3.7 | 4 |
| | Terlizzi | 76BA008 | 5505 | 9.0 | 8.0 | 9.5 | 00.0 | 5.8 | 3.0 | 4 |
| | Terlizzi | 76BA009 | 5507 | 9.0 | 7.2 | 8.8 | 00.0 | 7.4 | 4.0 | 4 |
| | Terlizzi | 76BA010 | 5503 | 12.1 | 9.6 | 11.0 | 3.6 | 6.4 | 4.7 | 4 |
| | Terlizzi | 76BA011 | 5504 | 10.7 | 9.0 | 10.8 | 3.7 | 6.3 | 4.0 | 4 |
| | Terlizzi | 76BA012 | 5501 | 19.5 | 18.0 | 18.5 | 7.0 | 10.8 | 4.7 | 4 |
| | Terlizzi | 76BA013 | 5502 | 20.0 | 19.0 | 19.5 | 8.0 | 10.6 | 5.0 | 4 |
| | Terlizzi | 76BA014 | 5500 | 18.0 | 17.0 | 17.5 | 6.8 | 9.0 | 4.4 | 4 |
| 6. | Cappuccini | 76MA004 | 4811 | 10.5 | 9.3 | 9.5 | 00.0 | 5.8 | 2.8 | 2 |
| 7. | S. Francesco | 76MA007 | 4846 | 11.0 | 10.2 | 11.1 | 00.0 | 5.4 | 2.5 | 2 |
| | S. Francesco | 76MA009 | 4844 | 19.0 | 18.0 | 20.5 | 7.0 | 10.8 | 5.0 | 2 |
| 8. | 'La Monaca' | 76MA010 | 4439 | 8.8 | 7.8 | 8.0 | 00.0 | 3.8 | 2.0 | 2 |
| 9. | S. Martino | 76MA011 | 4483 | 9.5 | 8.0 | 8.5 | 00.0 | 4.0 | 2.3 | 2 |
| | S. Martino | 76MA012 | 4431 | 13.3 | 13.3 | 14.5 | 00.0 | 8.3 | 3.5 | 2 |
| | S. Martino | 76MA013 | 4419 | 25.0 | 00.0 | 26.2 | 00.0 | 11.0 | 2.3 | 2 |
| | S. Martino | 76MA015 | 4403 | 26.0 | 00.0 | 27.0 | 8.8 | 12.0 | 2.5 | 2 |
| | S. Martino | 76MA016 | 4421 | 7.0 | 00.0 | 9.0 | 3.6 | 7.3 | 3.5 | 2 |
| | S. Martino | 76MA017 | 4417 | 99.9 | 10.0 | 11.0 | 0.0 | 7.3 | 4.0 | 2 |
| 10. | La Starza | 76NA007 | | 8.0 | 7.2 | 9.6 | 4.5 | 6.0 | 3.0 | 2 |
| | La Starza | 76NA008 | | 10.0 | 99.9 | 99.9 | 5.0 | 5.5 | 0.7 | 2 |
| | La Starza | 76NA009 | | 8.0 | 99.9 | 99.9 | 00.0 | 3.0 | 2.2 | 2 |
| | La Starza | 76NA010 | | 6.8 | 99.9 | 99.9 | 00.0 | 3.4 | 1.7 | 2 |
| | La Starza | 76NA011 | | 14.8 | 99.9 | 99.9 | 00.0 | 9.8 | 2.5 | 2 |
| | La Starza | 76NA012 | | 10.0 | 99.9 | 99.9 | 00.0 | 5.0 | 2.0 | 2 |
| | La Starza | 76NA013 | | 8.0 | 8.0 | 8.0 | 00.0 | 6.6 | 1.6 | 2 |
| 11. | Pertosa | 76NA014 | | 18.3 | 99.9 | 99.9 | 00.0 | 8.0 | 3.5 | 2 |
| | Pertosa | 76NA015 | | 12.7 | 99.9 | 99.9 | 00.0 | 5.1 | 2.2 | 2 |
| | Pertosa | 76NA016 | | 15.0 | 00.0 | 17.0 | 9.0 | 9.0 | 2.5 | 2 |
| | Pertosa | 76NA017 | | 9.0 | 00.0 | 00.0 | 5.0 | 6.0 | 0.0 | 2 |
| | Pertosa | 76NA018 | | 9.0 | 99.9 | 99.9 | 00.0 | 4.5 | 3.0 | 2 |

| | SITE | No. | Museum No. | DIAMETERS Rim | Neck | Shoulder | Base | HEIGHTS Total | Neck | Period** |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pertosa | 76NA019 | | 11.5 | 99.9 | 9.0 | 00.0 | 5.5 | 3.8 | 2 |
| | Pertosa | 76NA021 | | 6.3 | 99.9 | 8.0 | 4.5 | 6.5 | 1.5 | 2 |
| 12. | Murgia Timone | 76NA022 | 125627 | 8.7 | 99.9 | 99.9 | 00.0 | 4.5 | 1.5 | 4 |
| | Murgia Timone | 76NA023 | 125630 | 8.0 | 99.9 | 99.9 | 00.0 | 3.5 | 2.5 | 4 |
| | Murgia Timone | 76NA024 | 125629 | 8.8 | 99.9 | 99.9 | 00.0 | 2.2 | 1.7 | 4 |
| | Murgia Timone | 76NA025 | 125628 | 9.0 | 99.9 | 99.9 | 00.0 | 3.5 | 2.0 | 4 |
| 13. | Lipari | 76LI001 | 895 | 19.0 | 16.2 | 17.0 | 8.0 | 8.0 | 4.2 | 4 |
| | Lipari | 76LI002 | 5288 | 24.0 | 22.0 | 23.0 | 00.0 | 7.7 | 3.0 | 4 |
| | Lipari | 76LI003 | 889 | 15.2 | 14.0 | 15.0 | 00.0 | 3.5 | 3.0 | 4 |
| | Lipari | 76LI004 | 519 | 13.2 | 12.5 | 12.5 | 00.0 | 3.5 | 1.9 | 4 |
| | Lipari | 76LI005 | 5222 | 29.5 | 28.0 | 28.0 | 8.5 | 9.5 | 3.5 | 4 |
| | Lipari | 76LI006 | 513 | 12.0 | 10.4 | 12.0 | 5.0 | 4.8 | 2.2 | 4 |
| | Lipari | 76LI007 | 5205 | 10.9 | 00.0 | 00.0 | 4.5 | 99.9 | 00.0 | 4 |
| | Lipari | 76LI008 | 5206 | 10.1 | 10.1 | 10.1 | 4.8 | 4.3 | 1.8 | 4 |
| | Lipari | 76LI009 | 602 | 22.0 | 20.0 | 21.0 | 8.5 | 8.3 | 3.0 | 4 |
| | Lipari | 76LI010 | 5204 | 29.0 | 28.0 | 28.0 | 10.3 | 10.8 | 3.2 | 4 |
| | Lipari | 76LI011 | 5223 | 10.8 | 9.7 | 10.8 | 00.0 | 99.9 | 1.8 | 4 |
| | Lipari | 76LI012 | 5207 | 9.8 | 8.2 | 9.0 | 00.0 | 4.0 | 2.5 | 4 |
| | Lipari | 76LI013 | 5209 | 8.7 | 8.0 | 8.7 | 00.0 | 6.0 | 2.5 | 4 |
| 14. | Timmari | 76MA026 | 4745 | 19.1 | 16.5 | 20.0 | 00.0 | 11.3 | 5.0 | 4 |
| | Timmari | 76MA027 | 4645 | 10.0 | 9.2 | 10.8 | 00.0 | 6.4 | 2.5 | 4 |
| | Timmari | 76MA028 | 4646 | 10.5 | 10.1 | 11.2 | 00.0 | 6.0 | 3.2 | 4 |
| | Timmari | 76MA029 | 4750 | 9.0 | 8.5 | 10.3 | 00.0 | 5.0 | 2.0 | 4 |
| | Timmari | 76MA030 | | 18.5 | 17.0 | 19.0 | 7.0 | 9.8 | 4.5 | 4 |
| 15. | Borgo Panigale | 76BO001 | 2715 | 19.0 | 17.0 | 17.2 | 00.0 | 8.5 | 5.3 | 4 |
| | Borgo Panigale | 76BO002 | 2713 | 18.3 | 17.0 | 18.0 | 00.0 | 8.3 | 4.0 | 4 |
| | Borgo Panigale | 76BO003 | 3327 | 10.5 | 00.0 | 13.0 | 6.7 | 7.3 | 2.2 | 4 |
| | Borgo Panigale | 76BO004 | 1715 | 18.5 | 18.2 | 18.5 | 00.0 | 8.5 | 4.5 | 4 |
| 16. | Tosc. Imolese | 76BO018 | 1903 | 14.0 | 00.0 | 15.4 | 7.2 | 10.3 | 99.9 | 4 |
| | Tosc. Imolese | 76BO019 | | 17.2 | 16.2 | 17.2 | 5.7 | 8.3 | 4.3 | 4 |
| | Tosc. Imolese | 76BO020 | | 9.5 | 9.1 | 10.0 | 5.5 | 6.3 | 3.2 | 4 |
| | Tosc. Imolese | 76BO021 | | 9.0 | 8.8 | 9.9 | 00.0 | 6.0 | 2.5 | 4 |
| 17. | Prevosta | 76BO022 | 41591 | 19.5 | 18.0 | 19.5 | 11.0 | 9.1 | 3.3 | 4 |
| 18. | V. Cassarini | 76BO024 | 1030 | 11.9 | 00.0 | 00.0 | 00.0 | 4.3 | 00.0 | 4 |
| 19. | Tufariello | 76PR001 | | 15.8 | 15.0 | 17.4 | 00.0 | 11.1 | 5.0 | 2 |
| | Tufariello | 76PR002 | | 8.4 | 7.2 | 7.4 | 2.5 | 5.3 | 2.9 | 2 |
| | Tufariello | 76PR003 | | 12.9 | 12.0 | 12.3 | 00.0 | 5.7 | 2.1 | 2 |
| | Tufariello | 76PR004 | | 15.8 | 15.6 | 17.5 | 99.9 | 99.9 | 2.4 | 2 |
| | Tufariello | 76PR005 | | 20.8 | 18.7 | 22.2 | 99.9 | 99.9 | 4.1 | 2 |
| | Tufariello | 76PR006 | | 13.0 | 12.4 | 13.4 | 00.0 | 8.2 | 2.5 | 2 |
| | Tufariello | 76PR007 | | 18.2 | 18.0 | 22.0 | 99.9 | 99.9 | 2.7 | 2 |
| | Tufariello | 76PR008 | | 12.4 | 11.6 | 13.4 | 99.9 | 99.9 | 3.8 | 2 |
| | Tufariello | 76PR009 | | 10.2 | 9.4 | 9.9 | 99.9 | 99.9 | 2.8 | 2 |
| | Tufariello | 76PR010 | | 10.8 | 10.0 | 11.4 | 99.9 | 99.9 | 3.9 | 2 |
| | Tufariello | 76PR011 | | 6.6 | 6.2 | 7.0 | 0.0 | 4.1 | 2.2 | 2 |
| | Tufariello | 76PR012 | | 13.4 | 13.2 | 13.2 | 99.9 | 99.9 | 4.0 | 2 |
| | Tufariello | 76PR013 | | 17.6 | 16.8 | 17.4 | 99.9 | 99.9 | 3.4 | 2 |
| | Tufariello | 76PR014 | | 17.4 | 16.6 | 19.2 | 99.9 | 99.9 | 3.9 | 2 |

* 99.9 indicates measurement not available
00.0 indicates measurement not relevant (e.g., pointed base and hence no base diameter)

** 2: Protoapennine
4: Subapennine

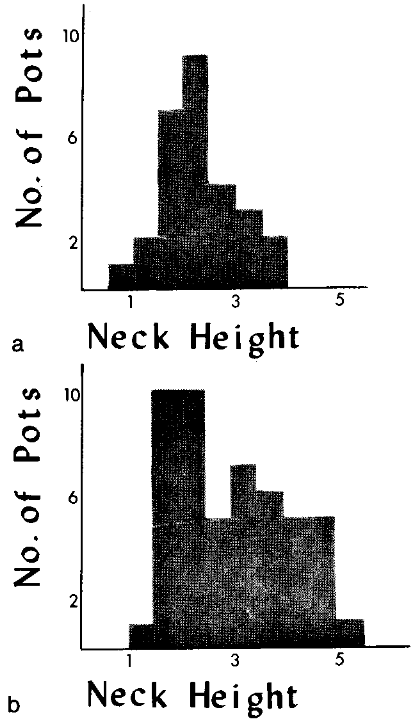


Figure 3. Neck height (cm.) histograms: a) Protoapennine cups; b) Subapennine cups.

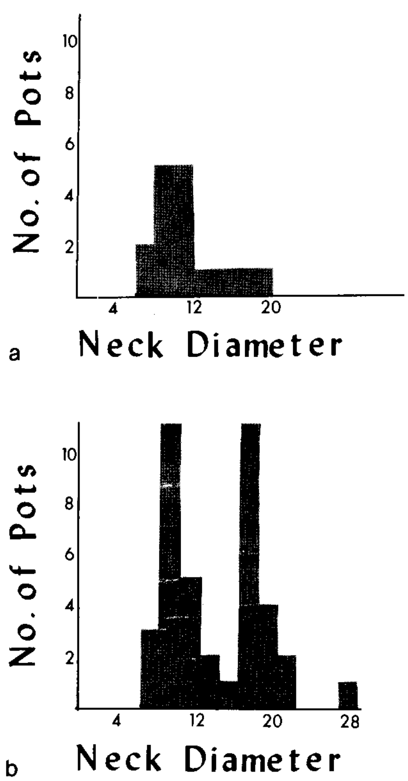


Figure 4. Neck diameter (cm.) histograms: a) Protoapennine cups; b) Subapennine cups.

quencies of cup measurements, one histogram for each period for each measurement. Basic to the data analysis was the comparison of each pair of measurement histograms (FIGS. 3 and 4). Three categories of relationships between such pairs of histograms appeared. For overall height, the histograms were similar; for neck height, Subapennine cups had large neck heights much more frequently than did Protoapennine cups (FIG. 3). For the three diameters, Subapennine cups again had large measurements much more frequently than did Protoapennine cups; concurrently, Subapennine diameters also exhibited a strong tendency to cluster into two groups of measurement ranges while the Protoapennine did not exhibit such a tendency (FIG. 4).

The second mathematical technique employed produced scatter diagrams showing the relationship between two of the five measurements for one period. One quantitative description of the relationship between the two sets of paired measurements $x_1, \ldots, x_n$ and $y_1, \ldots, y_n$ plotted in a scatter diagram is the sample correlation coefficient, denoted r, and given by the algebraic expression:

$$r = \frac{\sum_{i=1}^{n} (x_i - \overline{x})(y_i - \overline{y})}{\left[\left(\sum_{i=1}^{n} (x_i - \overline{x})^2\right)\left(\sum_{i=1}^{n} (y_i - \overline{y})^2\right)\right]^{1/2}}$$

where $\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$ and $\overline{y} = \frac{1}{n} \sum_{i=1}^{n} y_i$. The number r lies between $-1$ and $+1$; it is equal to $-1$ or to $+1$ only when the points in the scatter diagram lie on a straight line, and approaches 0 as the configuration of the points becomes increasingly random.

The correlation coefficients and the scatter diagrams for cup measurement pairs fell into three categories regardless of period (that is, Protoapennine or Subapennine): r between .33 and .39 with plots highly scattered (rim diameter vs. neck height, shoulder diameter vs. neck height); r from .56 to .82 with moderate scatter (neck diameter, rim diameter, and shoulder diameter each vs. overall height, shoulder diameter vs. neck height, neck height vs. overall height) (for example, FIG. 5); and r = .94 to r = .99 with plots highly linear (each pair of diameters) (for example, FIG. 6). While these scatter diagrams of one measurement against another failed to reveal more differences between periods, these diagrams nonetheless exhibited the same differences in relative frequency and clustering tendency as did the histograms.

Visual inspection of both histograms and scatter diagrams showed then that there are differences between the cups from the two periods, namely the different relative frequencies and the tendency for Subapennine diameter measurements to cluster. Distinction between cups of the two periods by analysis of histograms and scatter diagrams, however, is somewhat time-consuming and is not direct; it was desirable, therefore, to seek a simpler, more straightforward technique.

The desire to further quantify the differences between Protoapennine and Subapennine cups motivated use of multiple regression as the third mathematical procedure applied to the data. Histograms and scatter diagrams showed clearly that differences between cups of the two periods appeared in not one but several of the cup measurements. A regression equation provides a means for using a combination of the values of the five cup measurements to

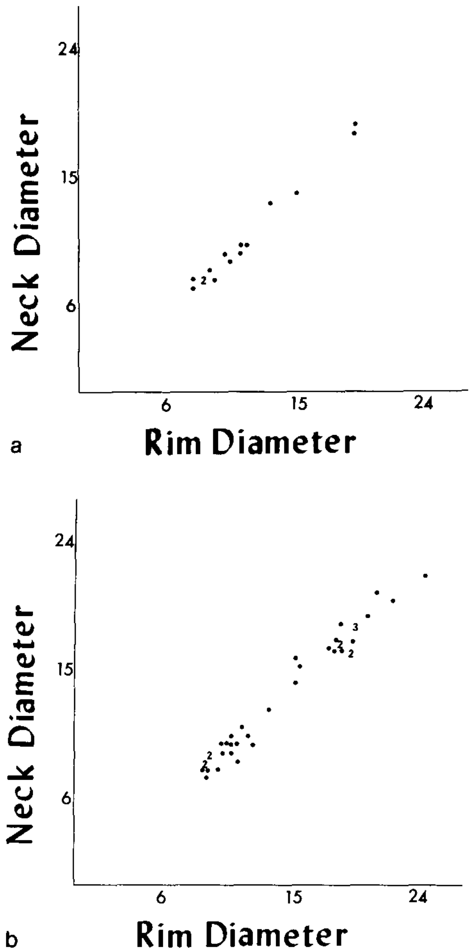


Figure 6. Scatterplots of neck diameter (cm.) vs. rim diameter (cm.): a) Protoapennine cups; b) Subapennine cups.

the correct period of a group of cups is seen to be possible because of differences in these values. The Subapennine mean is larger and the standard deviation greater than the corresponding Protoapennine values. The ranges do overlap, but the Protoapennine minimum is less than that for Subapennine, while the Subapennine maximum is substantially greater than the Protoapennine maximum. These differences are caused essentially by the differences in relative frequencies of measurements between cups of the two periods and the clustering tendency of Subapennine cups.

We now have a relatively easy technique for determining if a collection of Apennine cups, known to belong to only one of the two periods, is Protoapennine or Subapennine. Using the regression equation, first calculate the estimated period of each cup; then compute the range, mean, and standard deviation of all these estimated periods; next, compare these values to the values in the table; and finally assign the new cups to the period with which the range, mean, and standard deviation more closely agree. This procedure was in fact applied to the Protoapennine Tufariello cups as a control group, and the range, mean, and standard deviation agreed well with the original Protoapennine values (TABLE 2). The Tufariello cups were then added to the data set and a new equation calculated:

$$\begin{aligned}\text{Estimated period} = 2.367 &+ 0.168\,(\text{rim diameter})\\ &- 0.077\,(\text{shoulder diameter})\\ &- 0.025\,(\text{neck diameter})\\ &+ 0.088\,(\text{overall height})\\ &+ 0.203\,(\text{neck height})\end{aligned}$$

New ranges, means, and standard deviations were computed (TABLE 2).

Further refinement and validation of these equations will be possible with measurements from additional securely dated cups. The equations computed at this stage, however, will be useful as an additional tool in determining the period of a collection of cups.

## Conclusions

This analysis demonstrates not a clear bipartite division but rather what we choose to call two different ranges of measurement combinations (estimated periods), as expressed in the results from the regression equation (TABLE 2). Subapennine cups produced a wider range of estimated periods, while Protoapennine cups fell within a narrower range. A simplified description will perhaps illustrate this idea of "range": as the maximum diameter of the cup expanded, other diameters and heights were reduced and/or expanded to keep the measurement combination (estimated period) within the range. Clearly, on this basis, one cannot take the measurements of a solitary cup and state categorically if it is late or early, but a sample of cups from a single deposit will produce a range of values indicative of one phase or another. Because of the overlap in ranges, a given sample of Subapennine cups could produce values totally in the range of overlap and hence appear to be Protoapennine. But our evidence suggests that this is not likely since approximately 40% of Subapennine cups fell above the overlap range.

More important than the implications for the question of Subapennine versus Protoapennine may be the implications for the continuing study of prehistoric pottery. We feel that the analyses outlined above demonstrate not only the existence of a mental template[9] in the minds of prehistoric potters,

9. James Deetz has expressed well the concept of mental template: "The idea of the proper form of an object exists in the mind of the maker, and when this idea is expressed in tangible form in

estimate the true period of a cup. Among all possible straight line relationships between cup measurements and true period (2 for Protoapennine cups, 4 for Subapennine), the regression equation provides a best overall estimate of the true period in the sense of attaining the minimum value for the sum of squares of differences between true and estimated periods.

A regression equation was computed using the regression program provided in the *Statistical Package for the Social Sciences* (SPSS).[8] The precise equation developed is as follows:

$$\begin{aligned}\text{Estimated period} = 2.344 &+ 0.166\,(\text{rim diameter})\\ &- 0.046\,(\text{neck diameter})\\ &- 0.053\,(\text{shoulder diameter})\\ &+ 0.194\,(\text{overall height})\\ &- 0.086\,(\text{neck height}).\end{aligned}$$

If the relationship between a linear combination of cup measurements and the true period were linear, and if there were no errors in measuring the cups or assigning the period, the estimated period of a cup would equal its true period (and be either 2 or 4). On the other hand, if there were no differences between Protoapennine and Subapennine cups, for every cup the estimated period would be 3, the arithmetic mean of 2 and 4. Since the relationship between cup measurements and period is not linear, but there are differences between cups of the two periods, as revealed by the histograms and scatter diagrams, the characteristics of the estimated period from the regression will lie between the two extremes of perfect distinction and no distinction.

The substantial overlap of cup measurements between cups of the two periods, illustrated in the histograms, guarantees that estimates of periods from the regression will not cluster into two disjointed groups, one group of numbers near 2 for Protoapennine cups, and another near 4 for Subapennine. One may, however, anticipate that the average estimated period for Protoapennine cups will be smaller than for Subapennine cups. The different ranges of some cup measurements, also illustrated in the histograms, suggest there will also be differences in ranges and sample standard deviations of estimated periods for the two periods.

To verify these conjectures, for each period, the range, mean, and standard deviation of the estimated period were computed (TABLE 2). Identification of

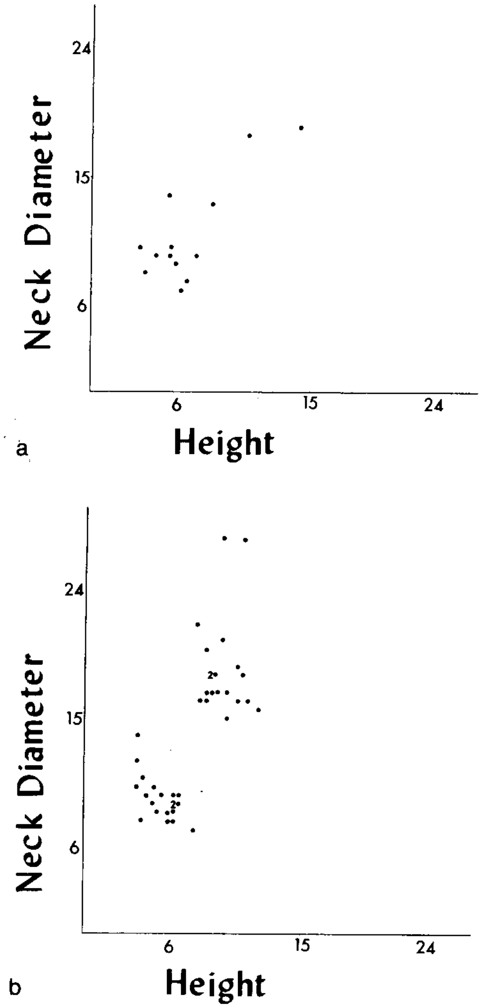


Figure 5. Scatterplots of neck diameter (cm.) vs. overall height (cm.): a) Protoapennine cups; b) Subapennine cups.

| Period | Statistic | Original Data | Tufariello Data | All Data |
|---|---|---|---|---|
| Protoapennine | Range | 2.6-3.6 | 2.9-3.3 | 2.6-3.6 |
| | Mean | 3.11 | 3.10 | 3.12 |
| | Standard deviation | 0.24 | 0.16 | 0.22 |
| Subapennine | Range | 2.8-4.3 | | 2.9-4.3 |
| | Mean | 3.44 | | 3.45 |
| | Standard deviation | 0.40 | | 0.40 |

Table 2. Descriptive statistics of cup period estimates calculated by the regression equations.

8. N. H. Nie, C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent, *Statistical Package for the Social Sciences* (New York 1975) 320-67.

but also how subtle can be the variations that occur among these templates of even closely related cultures. Visual proof that such a template exists can be found in the linearity of the scatter diagrams of one diameter against another (FIG. 6b is an example, with $r = .99$): regardless of overall height or neck height, the ratio of one diameter to another was almost constant, and no significant difference between the respective constants for the two periods was found. In the instance discussed in this paper, the variation has been shown mathematically; that this variation is subtle is demonstrated by the basic problem of the visual similarity of the fine ware of the two periods.

While size and proportion of wheel-made pots have generally been considered cultural factors (and design patterns on both hand-made and wheel-made equally as important in establishing cultural affinity), to date there is much scepticism about the importance of measurements of the hand-made material. We feel, however, that prehistoric cultures not only preferred specific pot shapes and sizes, but within the limits of what we may properly call a culture (as in the tradition extending from Protoapennine to Subapennine), there apparently existed certain preferences for variations of an individual shape.

These analyses demonstrate, we hope, both the existence of a precise mental template for hand-made pottery, as well as the possibilities for variation of this template within cultures and from culture to culture. Much more data will be necessary before this can be accepted as a firmly established cultural determinant but will, we expect, lead to the discovery of interesting patterns of variation in the prehistoric manufacture of pottery.

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raw material, an artifact results. The idea is the mental template from which the craftsmen make the objects." *Invitation to Archaeology* (Garden City 1967) 45.

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