In memory of J. Robert Butler
Abstract

Decades of archaeological work on Fort Bragg have revealed thousands of prehistoric sites that were inhabited by Indian peoples before the arrival of the Europeans. It is believed that many of these sites were temporary camps occupied by hunters and gatherers whose territories extended far beyond the boundaries of the modern fort. Thus, understanding the archaeology of Fort Bragg requires that these sites be placed in a larger geographical framework.

One way that modern archaeologists can trace the movements of ancient hunter-gatherers is through geological and geochemical studies that identify the sources of the raw materials used to make the artifacts found at archaeological sites. Such “sourcing” or “provenance” studies have the potential to delineate the territories over which hunter-gatherers traveled in the course of their yearly round of activities.

With these considerations in mind, the present study was designed to achieve two main objectives: (a) to evaluate the effectiveness of a range of mineralogical and chemical techniques for “fingerprinting” potential sources of raw materials, and (b) to apply these techniques in determining the sources of ancient stone tools found at Fort Bragg.

As a first step, 71 rock samples were collected from 12 different quarry zones, which were believed to be likely sources from which the prehistoric inhabitants of Fort Bragg obtained their stone; 11 of these quarry zones were located in the Piedmont (specifically in the Carolina Slate Belt), and one was located in the Coastal Plain. In addition, nine artifacts were selected from archaeological sites on Fort Bragg; all were Savannah River Stemmed points dating to the Late Archaic period (ca. 3000–1000 BC). The mineralogical and chemical composition of these 80 samples was then determined using five different techniques: petrography, neutron activation analysis (NAA), neodymium-isotope analysis, x-ray fluorescence (XRF), and inductively coupled plasma mass spectrometry (ICP-MS).

Petrographic analysis, supplemented by XRF, revealed that each quarry zone was marked by a distinctive suite of metavolcanic and/or metasedimentary rocks. A more general distinction was also seen between the northern and southern portions of the study area. The northern zones contained a mixture of metavolcanic and metasedimentary rocks and showed lower degrees of metamorphism. The southern zones were dominated by metavolcanic rocks and showed higher degrees of metamorphism. Of the nine artifacts examined, only two could be confidently matched with particular quarry zones. The rest could only be tentatively assigned to quarry zones or not assigned at all.

The study of elemental composition based on NAA revealed eight chemical groups among the quarry samples. When the elemental composition of the nine artifacts was compared to these groups, the results suggested that seven came from quarry zones in the southern Uwharrie Mountains. The assignment of the other two artifacts was unclear.

The analysis of neodymium (Nd) isotopes, supplemented by rare-earth elements as measured by ICP-MS, also revealed some interesting patterns. Different quarry zones were marked by distinctive, yet sometimes overlapping, ranges of Nd-isotope ratios. Even more interesting was a general trend of increase in the value of this ratio as one moves from south to north along the Carolina Slate Belt. This trend appears to be very consistent for the metavolcanic rocks and less so for the metasedimentary rocks. Based on these isotope ratios and the rare-earth data, one artifact was confidently assigned to the Orange County zone in the northern portion of the study.
area, four were assigned to the Uwharrie Mountains in the southern portion of the study area, and four were left unassigned.

When the results of these studies were compared, we found that each provided useful information, but that there were significant discrepancies among the assignments of artifacts to geological sources made by different researchers using different lines of evidence. Indeed, there was not a single case in which all three lines of evidence produced exactly the same assignment. This illustrates the need to look at all the lines of evidence together in making such assignments. The most reliable interpretations came from a synthetic approach that considered and weighed the different lines of evidence together. Based on this approach, we were able to conclude with some confidence that two artifacts came from the northern portion of the study area (including one from the Orange County zone), three came from the Uwharrie Mountains in the southern portion of the study area, and two may have come from the Uwharrie Mountains or even farther south. Two artifacts remained unassigned.

Based on this pilot study, we now have a much better understanding of the relative utility of the different techniques for sourcing artifacts from Fort Bragg. The two most useful techniques proved to be petrography and Nd-isotope analysis, although the elemental data (NAA, XRF, and ICP-MS) were also very helpful in certain cases. Nd-isotope analysis has the additional advantage of producing reliable results with very small samples of rock, which makes it particularly valuable for sourcing artifacts nondestructively.

We also now have a somewhat better idea of how ancient people moved over the landscape, at least for Late Archaic times, when the artifacts in our study were manufactured and used. The artifact assignments just described suggest that Late Archaic inhabitants of Fort Bragg utilized a number of quarries scattered over a wide area. Before being discarded, the artifacts had been carried over the linear distance between Fort Bragg and the Carolina Slate Belt quarries, minimally some 70–80 km. Given the non-linear patterns of movement often seen among hunter-gatherers, the actual distances involved may well have been over 200 km.

We recommend further studies of quarries in the Carolinas and artifacts from Fort Bragg. Additional quarries in the Piedmont should be sampled in order to refine our understanding of their chemical fingerprints and to answer some of the questions raised by this pilot study. It is especially important, for example, to sample areas south of the Uwharrie Mountains in order to see if the north-south trend in Nd ratios continues in this direction. We also need to learn more about the composition of rocks from the Coastal Plain. The sample of Fort Bragg artifacts should also be expanded to include both a wider variety of materials and periods other than the Late Archaic.
# Table of Contents

Abstract  v
List of Figures  ix
List of Tables  xii
Preface  xiii

1. Introduction  1
   - Archaeology of Fort Bragg  2
   - Sourcing Metavolcanic Rocks  5
   - Research Design  6

2. The Carolina Slate Belt  10
   - Ancient History  11
   - Rock Types  11
   - Stratigraphy  13
   - Topography and Human History  14

3. Quarries and Artifacts  16
   - Quarry Sites  16
   - Artifacts  36

4. Petrography  42
   - Geological Setting  43
   - Petrographic Criteria for Characterizing Specimens  43
   - Rock Names  48
   - Results  50
   - Petrographic Descriptions of Artifacts  65
   - Summary  74

5. Geochemistry: Elements  76
   - Analytical Methods  76
   - Quantitative Analysis of the Chemical Data  77
   - Results and Conclusions  79

6. Geochemistry: Neodymium Isotopes  90
   - Background  90
   - Results  93
   - Summary and Conclusions  97

7. Conclusions  98
   - Petrography  98
   - Geochemistry: Elements  100
Geochemistry: Isotopes 104
Discussion and Synthesis 107
Evaluation of Methods 113
Archaeological Implications and Future Directions 116

Appendices
A. Sample Descriptions 120
B. Quarry Database 137
C. Petrographic Data 156
D. Neutron Activation Analysis Data 161
E. X-Ray Fluorescence Spectrometry Data 169
F. Inductively Coupled Plasma Mass Spectrometry Data 175
G. Neodymium Isotope Geochemistry 179

Bibliography 182
List of Figures

1.1. Selected diagnostic hafted bifaces, metavolcanic material, Fort Bragg 3
1.2. A blank and biface cache, metavolcanic material, Fort Bragg 5
1.3. The geographic distribution of quarries, quarry zones, and artifacts used in this study 7
2.1. Major geologic regions of North Carolina 11
2.2. Geologic features in the vicinity of the Uwharrie Mountains 12
2.3. North Carolina rivers and drainage basins mentioned in the text 14
3.1. Recorded quarry sites in the Carolina Slate Belt of North Carolina 17
3.2. Sample locations mapped by county 21
3.3. Sample locations mapped by geologic formation 22
3.4. Quarry zones and sample locations in the Uwharrie Mountains 23
3.5. Jeffrey Irwin collecting quarry debris on Lick Mountain in the general vicinity of site 31Mg222, Uwharries Southeastern zone 24
3.6. Dense quarry debris from erosional gulley on Morrow Mountain, Uwharries Southern zone 25
3.7. Brent Miller collecting samples on Wolf Den Mountain, Uwharries Western zone 26
3.8. Edward Stoddard collecting outcrop sample (FBL055) at site 31Rd1350, Uwharries Asheboro zone 27
3.9. Quarry zones and sample locations in the northern portion of the study area 28
3.10. Quarry debris at site 31Ch729, Chatham Pittsboro zone 29
3.11. Quarry debris used for landscaping near site 31Ch729, Chatham Pittsboro zone 29
3.12. Rock with parallel bedding still visible, Chatham Pittsboro zone 30
3.13. Eroded roadbed and dense quarry debris at site 31Ch741, Chatham Silk Hope zone 31
3.14. Quarry debris seen through dense leaf litter at the Bald Mountain quarry, Orange County zone 32
3.15. Brent Miller and Edward Stoddard collecting outcrop sample (FBL065) at site 31Or549, Orange County zone 33
3.16. Dense quarry debris in upturned tree roots at site 31Dh703, Durham County zone 33
3.17. Boulder from which sample FBL067 was taken, Durham County zone 35
3.18. Dense quarry debris on largest ridge at site 31Pr115 (near FBL069), Person County zone 35
3.19. Artifacts used in this study, all Savannah River Stemmed points 37
3.20. Artifact locations on Fort Bragg 38
4.1. IUGS classification for volcanic igneous rocks 49
4.2. Total alkalis versus silica (TAS) classification of volcanic rocks 50
4.3. Typical Uwharries Eastern sample with quartz and plagioclase phenocrysts 53
4.4. Strongly flow-banded dacite with quartz and plagioclase phenocrysts 53
4.5. Metamorphic stilpnomelane (needle-like aggregates) in Uwharries Eastern sample 54
4.6. Uwharries Western sample with sparse plagioclase phenocrysts and fine groundmass 54
4.7. Uwharries Southern sample with spherulites 55
4.8. Uwharries Asheboro sample with mineral clusters of pyrite + calcite + epidote 56
4.9. Garnet porphyroblasts in Uwharries Asheboro sample 56
4.10. Uwharries Southeastern sample with quartz and plagioclase phenocrysts and weak banding 58
4.11. Uwharries Southeastern sample with circular quartz amygdules and sparse phenocrysts 58
4.12. Chatham Pittsboro sample with fine laminae, grading, possible current ripples, and incipient cleavage 59
4.13. Chatham Pittsboro sample with graded bedding couplets 59
4.14. Basaltic fragment in Chatham Silk Hope sample 60
4.15. Y-shaped glass shard in Chatham Silk Hope sample 60
4.16. Piedmontite in groundmass of Chatham Silk Hope sample 61
4.17. Euhedral and resorbed quartz phenocrysts, with plagioclase, in Orange County sample 62
4.18. Durham County volcanic sandstone with clastic texture 63
4.19. Person County sample with sedimentary laminae, grading, and microfaults 64
4.20. Elliptical feature (perhaps a trace fossil?) in metasiltsone from Person County 64
4.21. Artifact FBL072 67
4.22. Groundmass lath alignment, plagioclase phenocryst, and garnet porphyroblasts in artifact FBL072 67
4.23. Artifact FBL073 68
4.24. Artifact FBL074 70
4.25. Artifact FBL075 70
4.26. Artifact FBL076 71
4.27. Artifact FBL077 71
4.28. Artifact FBL078 72
4.29. Weak alignment, phenocrysts, and pseudomorphs after amphibole or pyroxene in artifact FBL078 72
4.30. Artifact FBL079 73
4.31. Artifact FBL080 74
5.1. Biplot derived from PCA of the variance-covariance matrix of the NAA data showing principal component 1 versus principal component 2 81
5.2. Biplot derived from PCA of the variance-covariance matrix of the NAA data showing principal component 3 versus principal component 1 82
5.3. Bivariate plot of Zr versus La for the chemical groups 83
5.4. Bivariate plot of Ta versus Hf for the chemical groups 83
5.5. Bivariate plot of Rb versus Eu for six of the chemical groups 84
5.6. Bivariate plot of Ta versus Fe for six of the chemical groups 84
5.7. Bivariate plot of Th versus Cs for six of the chemical groups 85
6.1. Conventional Sm/Nd isochron diagram 92
6.2. Conventional isochron diagram showing isotope ratio plots for quarry and artifact samples 94
6.3. Isotope and trace element ratio plot for quarry and artifact samples showing Nd isotopes calculated at 550 Ma (the nominal age of rocks in the Uwharries) versus La/Lu 96
6.4. Isotope and trace element ratio plot for quarry and artifact samples showing Nd isotopes calculated at 550 Ma (the nominal age of rocks in the Uwharries) versus Ta/Yb

7.1. Geographical distribution of quarry zones

7.2. Dot plot showing Nd-isotope ratios for quarry zones and artifacts

7.3. Map showing the likely source areas for Late Archaic artifacts from Fort Bragg

A.1. Samples FBL001-FBL010
A.2. Samples FBL011-FBL020
A.3. Samples FBL021-FBL030
A.4. Samples FBL031-FBL040
A.5. Samples FBL041-FBL050
A.6. Samples FBL051-FBL060
A.7. Samples FBL061-FBL070
A.8. Sample FBL071
A.9. Artifacts FBL072-FBL080

B.1. Sample locations in the Uwharries Southeastern zone
B.2. Sample locations in the Uwharries Southern zone
B.3. Sample locations in the Uwharries Eastern zone
B.4. Sample locations in the Uwharries Western zone
B.5. Sample locations in the Uwharries Asheboro zone
B.6. Sample locations in the Chatham Pittsboro zone
B.7. Sample locations in the Chatham Siler City zone
B.8. Sample locations in the Chatham Silk Hope zone
B.9. Sample locations in the Orange County zone
B.10. Sample locations in the Durham County zone
B.11. Sample locations in the Person County zone
B.12. Sample locations in the Cumberland County zone
B.13. Artifact sample locations, all on Fort Bragg
# List of Tables

1.1. Distribution of Quarry Samples, Phases 1 and 2  8  
3.1. Quarry Samples Used in the Present Study  18  
3.2. Fort Bragg Artifact Samples  36  
4.1. Rock Samples Examined, with Selected Normative Values and Classification  44  
4.2. Fort Bragg Artifacts Examined, with Selected Normative Values and Classification  46  
4.3. Practical Field Guide to Volcanic Rock Classification  49  
4.4. Petrographic Features of Quarry Zones  51  
4.5. Petrographic Features of Fort Bragg Artifacts  66  
5.1. Principal Components Analysis  80  
5.2. Element Means and Standard Deviations Within Chemical Groups  86  
5.3. Rock Samples Arranged by Chemical Group, with Mahalanobis Probabilities of Membership in the Uwharrie 1 Group  87  
5.4. Fort Bragg Artifacts, with Mahalanobis Probabilities of Membership in the Uwharrie 1 Group  89  
7.1. Selected Petrographic Features of Quarry Zones  99  
7.2. Selected Petrographic Features and Assignments of Fort Bragg Artifacts  101  
7.3. Assignment of Quarry Zones to Chemical Groups, Based on Neutron Activation Analysis  103  
7.4. Assignments of Fort Bragg Artifacts to Chemical Groups, Based on Neutron Activation Analysis  103  
7.5. Mahalanobis Probabilities of Group Membership, Based on Four Principal Components  105  
7.6. Assignments of Fort Bragg Artifacts to Quarry Zones, Based on Nd-Isotope Ratios  107  
7.7. Summary of Source Assignments for Fort Bragg Artifacts  108  
A.1. Descriptive Information for Rock Samples: Provenience  121  
A.2. Descriptive Information for Rock Samples: Geology  124  
A.3. Descriptive Information for Artifact Samples: Provenience, Geology, and Type  127  
A.4. Descriptive Information for Artifact Samples: Measurements  127  
B.1. Quarry Database  138  
C.1. Selected Petrographic Characteristics  157  
D.1. Element Concentrations as Measured by Neutron Activation Analysis (As-Sb)  163  
D.2. Element Concentrations as Measured by Neutron Activation Analysis (Sc-V)  166  
E.1. Major Element Concentrations as Measured by X-Ray Fluorescence  171  
E.2. Trace Element Concentrations as Measured by X-Ray Fluorescence  173  
F.1. Element Concentrations as Measured by Inductively Coupled Plasma Mass Spectrometry  176  
G.1. Neodymium (Nd) and Samarium (Sm) Isotope Ratios  180
The research presented in this volume was prompted by two simple questions: Where did the ancient inhabitants of Fort Bragg come from, and how did they move over the landscape? As our knowledge of prehistoric settlements on Fort Bragg grew, it became increasingly clear that these sites could not be understood in isolation. Rather, many seemed to be temporary camps of people whose territories extended far beyond the bounds of the present-day military base. The only way to reconstruct these ancient territories archaeologically would be to trace the movements of the artifacts that these people carried with them. This objective could best be accomplished by linking the artifacts to their geological sources — that is, by “fingerprinting” the raw materials from which the artifacts were made and matching the fingerprints with particular outcrops of stone. The methods were well established; yet very few such studies had ever been done in the Carolinas.

It was clear from the outset that our questions could only be answered by a collaborative project involving both geologists and archaeologists. The archaeological impetus for this project was provided by Jeff Irwin and Chris Moore. A number of scholars were then recruited for their geological and geochemical skills: Skip Stoddard for his knowledge of petrography and local rocks, Brent Miller and Drew Coleman for their expertise in isotope geochemistry, and Mike Glascock and Jeff Speakman for their expertise in element geochemistry and archaeological sourcing. Vin Steponaitis and John Rogers were brought in to provide additional perspectives and to help design and coordinate the research. Once the work was underway, Theresa McReynolds joined the team in order to help edit and produce the report.

The analysis of archaeological and geological samples took place over a period of two years at three different laboratories, each working independently. The petrography was done by Skip Stoddard at North Carolina State University; neutron activation, x-ray fluorescence, and inductively coupled plasma mass spectrometry were carried out by Mike Glascock, Jeff Speakman, and their colleagues at the University of Missouri in Columbia; and the neodymium-isotope analysis was done by Brent Miller and Drew Coleman at the University of North Carolina at Chapel Hill. The results were then discussed and compared by the research group as a whole, a fruitful process that led to the synthetic conclusions presented in Chapter 7.

Needless to say, many other individuals provided crucial help in bringing this project to a successful conclusion. Wayne Boyko, Tad Britt, and Paul Webb provided leadership, administrative support, and constructive oversight, without which this project would never have gotten off the ground and kept moving. Tim Brown shared his computer expertise at many points along the way. Mary Ayers, Randy Daniel, Steve Davis, Mike Harmon, Brett Riggs, and Ken Robinson provided archaeological advice and assisted greatly in identifying and collecting samples. Dolores Hall and John Mintz helped in working with the North Carolina site files. And many avocational archaeologists — among them Robert Graham, Mark McCravey, and Joe Moylan — shared their knowledge of quarry sites throughout the Carolina Slate Belt. To all these colleagues and friends, we express our sincere gratitude.