A Structural Approach to Lapita Ceramic Design Analysis: Investigation of the Eastern Lapita Province

by

Kathleen G. LeBlanc

M.A., Simon Fraser University, 2011
B.A. (Hons.), Memorial University of Newfoundland, 2009

Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

in the

Department of Archaeology
Faculty of the Environment

© Kathleen G. LeBlanc 2016

SIMON FRASER UNIVERSITY

Spring 2016

All rights reserved. However, in accordance with the Copyright Act of Canada, this work may be reproduced, without authorization, under the conditions for “Fair Dealing.” Therefore, limited reproduction of this work for the purposes of private study, research, criticism, review and news reporting is likely to be in accordance with the law, particularly if cited appropriately.
Approval

Name: Kathleen LeBlanc
Degree: Doctor of Philosophy
Title: A Structural Approach to Lapita Ceramic Design Analysis: Investigation of the Eastern Lapita Province

Examining Committee:

Chair: Dongya Yang
Professor

David Burley
Senior Supervisor
Professor

Mark Collard
Supervisor
Professor

Ross Jamieson
Internal Examiner
Associate Professor
Department of Archaeology

Scarlett Chiu
External Examiner
Associate Research Fellow
Institute of History and Philology
Academia Sinica

Date Defended/Approved: March 24, 2016
Abstract

Methodological approaches to archaeological ceramic design analysis often rely upon the subjective identification and comparison of decorative design elements and motifs. In an effort to develop more objective methods, I propose and evaluate the utility of a new structural approach that quantifies the complexity and organization of design, predominantly through the use of microscopy techniques. The approach is compared to element/motif analysis and applied to data sets of Lapita ceramics, the ceramic series that demarcates exploration and first settlement by Austronesian speaking peoples across Oceania. I am first concerned with the Eastern Lapita Province (Fiji, Lau, Tonga and Samoa), a region that is known to share motifs, but differs in motif application and layout. Applying both motif and structural analysis, I not only identify variation in results between the two methods but distinguish and isolate regional ceramic variation. This, then, leads me to question the cohesiveness of the Eastern Lapita Province as it is previously defined. Second, I extend my analysis to incorporate ceramic samples from the Western (Vanuatu) and Southern (New Caledonia) Lapita provinces. Ostensibly, I define ancestral relationships between these regions as Oceania was explored and settled by Lapita peoples. Finally, I apply this approach to Lapita ceramic assemblages across the Tongan archipelago. High precision dating of ceramic assemblages in Tonga, combined with motif and structural analysis, gives insight into the cohesiveness of a Lapita potting community and the rapid disappearance of decorative applications within a century and a half after colonization.

Difference in results provided by structural versus element/motif analysis could be due to several factors, including cultural transmission mechanisms through which potters choose designs and then place them onto a pot. These mechanisms have yet to be identified through hypotheses tested with both structural and element/motif ceramic design data employing a single data set. This study presents an important step in this direction for Lapita archaeology. Elements and motifs are no doubt important for the analysis of design, but structural application can and should be used as a complementary approach in order to understand the degree to which both aspects of design signal potter interaction.
Keywords: Ceramic design analysis; structural design analysis; Lapita archaeology; Eastern Lapita Province; confocal microscopy
For my family
Acknowledgements

I would like to take this opportunity to thank several individuals and institutions. First I would like to thank my senior supervisor, Professor David Burley for providing intellectual contributions towards the design of this research project and for guidance related to the PhD process in general. As my MA and PhD supervisor he has introduced and guided me through the field of Lapita archaeology, for which I am grateful. Professor Mark Collard as my supervisory committee member provided insightful edits for previous drafts of this dissertation. I am indebted towards Dr. Geoff Irwin, Dr. Simon Best, Dr. Stuart Bedford, Dr. Christophe Sand and the Fiji Museum for loaning ceramic samples that were analyzed during this research study. Ian Bercovitz, Director of the Statistical Consulting Service at Simon Fraser University, provided essential guidance towards the statistical analyses used throughout this dissertation for which I am very grateful. Dr. Heejae Lang at The Advanced Materials and Process Engineering Lab at the University of British Columbia kindly provided training for the Olympus LEXT 4000 and enabled me to use the machine for my sample analysis. I would also like to thank Dr. Scarlett Chiu for acting as external examiner and Dr. Ross Jamieson for acting as internal examiner for the defence of this dissertation and for their insightful edits to the final draft. Vienna Chichi Lam kindly assisted in figure preparations. Travis Freeland, Kody Huard, Megan Wong and multiple others in the graduate student program at Simon Fraser University provided assistance and guidance throughout the dissertation process. Special thanks goes to the Social Sciences and Humanities Research Council of Canada for providing funding to undertake this project. I would also like to thank the Department of Archaeology at Simon Fraser University for both financial and academic support in this research endeavour. Finally, I would like to sincerely thank Norm, Brenda, Nicki, and Adam for providing emotional support every step of the way. I could not have completed this without your help; thank you!
# Table of Contents

Approval................................................................................................................................. ii  
Abstract................................................................................................................................. iii  
Dedication................................................................................................................................. v  
Acknowledgements..................................................................................................................... vi  
Table of Contents...................................................................................................................... vii  
List of Tables............................................................................................................................ x  
List of Figures ........................................................................................................................... xv  

## Chapter 1. Introduction to Lapita Ceramic Design Analysis................................. 1  
1.1. Ceramic Design Analysis in the Context of Lapita Archaeology .................. 6  
1.2. Lapita Ceramic Design Methods: The Problem ............................................. 8  
1.3. A New Structural Approach to Lapita Ceramic Design Analysis ............ 11  
1.4. Case Studies..................................................................................................................... 11  
\hspace{1cm} 1.4.1. Case Study 1: The Eastern Lapita Province................................. 12  
\hspace{1cm} 1.4.2. Case Study 2: A View from Outside.................................................... 14  
\hspace{1cm} 1.4.3. Case Study 3: A View from Within......................................................... 15  
1.5. Organization of Dissertation....................................................................................... 16  

## Chapter 2. Context for the Development of a Structural Approach to Lapita Ceramic Design Analysis ........................................................... 18  
2.1. Lapita Archaeology as Viewed through a Ceramic Lens ..................................... 22  
\hspace{1cm} 2.1.1. Ceramic Production and Exchange ......................................................... 26  
2.2. Debate Concerning the Eastern Lapita Province ............................................... 27  
\hspace{1cm} 2.2.1. Conflicting Results from Element/Motif Ceramic Design Analysis .......... 29  
2.3. Ceramic Design Analysis in Cross-Cultural Perspective ............................... 35  
\hspace{1cm} 2.3.1. Element/Motif Approach ........................................................................ 36  
\hspace{1cm} 2.3.2. Structural Approaches ........................................................................... 38  
\hspace{1cm} 2.3.3. Current Approaches to Ceramic Design Analysis ............................... 43  
\hspace{1cm} 2.3.4. Conclusions Drawn from Ceramic Design Analysis ............................. 45  
\hspace{1cm} 2.3.5. Lessons for Lapita Ceramic Design Analysis ......................................... 47  
2.4. Chapter Summary............................................................................................................. 48  

## Chapter 3. Theoretical Framework for Developing a Structural Approach: Cultural Transmission Theory .................................................. 50  
3.1. Cultural Transmission in the Context of Dual Inheritance Theory .................... 53  
3.2. Archaeological Applications of CT Theory ......................................................... 57  
\hspace{1cm} 3.2.1. Individual-level CT .................................................................................. 58  
\hspace{1cm} 3.2.2. Group-level CT ....................................................................................... 59  
3.3. Research Design............................................................................................................ 65  
\hspace{1cm} 3.3.1. Use of CT Tenants to Develop a Structural Approach to the Study of Lapita Ceramic Design ......................................................................................... 66  
\hspace{1cm} 3.3.2. Case Study 1: The Eastern Lapita Province ................................................ 67
Chapter 4. Methodology for a Structural Approach to Lapita Ceramic
Design Analysis ................................................................. 71
  4.1. Attributes ..................................................................... 72
     4.1.1. Continuous attributes ........................................... 72
            Microscope techniques ............................................ 72
     4.1.2. Nominal Variables ................................................ 80
  4.2. Archaeological Ceramic Assemblages .............................. 85
     4.2.1. Microscope Analysis ............................................. 87
            Statistical Analysis .................................................. 88
  4.3. Chapter Summary ........................................................ 89

Chapter 5. Case Study 1 – The Eastern Lapita Province .............. 90
  5.1. Methods ................................................................. 90
     5.1.1. Archaeological Samples ........................................ 91
     5.1.2. Attribute Analysis .............................................. 95
  5.2. Results ................................................................... 95
  5.3. Discussion .............................................................. 112

Chapter 6. Case Study 2 - A View from the West: Comparison of Lapita
Design Beyond the Eastern Lapita Province ............................. 116
  6.1. Methods .............................................................. 116
     6.1.1. Archaeological Samples ....................................... 117
            Attribute Analysis .................................................. 118
  6.2. Results ................................................................ 119
  6.3. Discussion .............................................................. 143

Chapter 7. Case Study 3 - A View from Within: Lapita Design Through
Time in the Tongan Archipelago .............................................. 147
  7.1. Methods .............................................................. 147
     7.1.1. Archaeological Samples ....................................... 149
            Attribute Analysis .................................................. 150
  7.2. Results ................................................................ 151
  7.3. Discussion .............................................................. 162

Chapter 8. Discussion and Conclusion...................................... 166
  8.1. The New “Shape” of the Eastern Lapita Province ............. 167
     8.1.1. Comparison with Previous Studies from the Eastern Lapita Region ......... 167
            Comparison with the Western and Southern Lapita Province .......... 169
8.1.3. Interaction in the Tongan Archipelago through Time ....................... 172
8.2. What the Structural Approach Reveals about Lapita Ceramic Design
   Analysis ........................................................................................................... 174
   8.2.1. The Structural approach and Lapita Design ........................................ 174
   8.2.2. Results in Light of the Element/Motif Approach ................................. 175
8.3. CT Theory: Insights into Design Variation .............................................. 176
8.4. Where Should Lapita Ceramic Design Analysis go from Here? ............. 180
8.5. Conclusion .................................................................................................. 182

References ........................................................................................................ 185

Appendix A. Ceramic Attribute Data ................................................................. 214
Appendix B. Raw Attribute Data ................................................................. 215
Appendix C. Ceramic Photo Catalogue ......................................................... 216
List of Tables

Table 4.1. Attributes used to analyze Lapita ceramic design. ............................................. 74

Table 4.2. Extension and variation on Lapita design elements outlined in Chiu and Sand (2005). These are used to construct structural rules as outlined in Sharp (1988) and shown in Appendix A. ................. 83

Table 5.1. Sample size used for Case Study 1. Samples were selected either through random sampling or through a grab sample for a total of 25 sherds per sample group. The number of ceramic sherds from each site that were analyzed using the Olympus LEXT 4000 are also indicated, with a total of 10 for each sample group. See Appendix A for detailed information on sherds, including catalogue numbers. ................................................................. 92

Table 5.2. P-values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 and LEXT 4000 attributes for the Eastern Lapita region. Significance is denoted by asterisk. Significance indicates that dentate density is a significant predictor of dentate attributes and must be controlled for in subsequent analysis. ........................................................................ 96

Table 5.3. Post-hoc comparisons of density attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which groups differ significantly by indication of statistical p values. Statistical significance is determined at an α level calculated using the Benjamini-Hochberg method. ........................................... 97

Table 5.4. P-values derived from comparison of means between the four sample groups in the Eastern Lapita Province using ANCOVA. Asterisk indicates statistical significance at α=0.05................................. 98

Table 5.5. Post-hoc comparisons of attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical p values. Statistical significance is determined at different α values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The α values were determined using the Benjamini-Hochberg method......................................................... 99

Table 5.6. P-values derived from comparisons of means between the four sample groups using ANCOVA. Asterisk indicates statistical significance at α=0.05. ................................................................. 101
Table 5.7. Post-hoc comparisons of attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical $p$ values. Statistical significance is determined at different $\alpha$ values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The $\alpha$ values were determined using the Benjamini-Hochberg method. 102

Table 5.8. $P$ values derived from Fischer’s Exact test to determine the significance of association between attributes and ceramic sherds from the four sample groups. Asterisk indicates statistical significance at $\alpha = 0.05$. 104

Table 5.9. Post-hoc comparisons of motif infilling between four Lapita samples from the Eastern Lapita Province as determined through individual Fischer’s Exact tests. The $\alpha$ value was determined using the Benjamini-Hochberg method. 105

Table 5.10. $P$ values derived from bivariate linear fit regression between dentate density, sherd length, sherd width, and the number of elements, motifs, and processes per sherd for the Eastern Lapita region. Significance is denoted by asterisk. Significance indicates that dentate density, sherd width, and/or sherd length are significant predictors of attributes and must be controlled for in subsequent analysis. 105

Table 5.11. Post-hoc comparisons of element and motif frequency values resulting from individual Fischer’s Exact tests between sample groups in the Eastern Lapita Province. The $\alpha$ value was determined using the Benjamini-Hochberg method. 106

Table 5.12. Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. Element code refers to the updated Chiu and Sand (2005) system presented in Table 4.2. 109

Table 5.13. Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system. 111

Table 5.14. Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. Process code used is that outlined in Sharp (1988). 112
Table 6.1. P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 and LEXT 4000 attributes for the Eastern, Southern, and Western Lapita sample groups. Significance is denoted by asterisk. Significance indicates that the covariate is a significant predictor of dentate attributes and must be controlled for in subsequent analysis. ................................................................. 120

Table 6.2. Post-hoc comparisons of density attribute distribution between Lapita samples from the Eastern, Western, and Southern Provinces. Chart indicates which groups differ significantly by indication of statistical $p$ values. Statistical significance is determined at an $\alpha$ level calculated using the Benjamini-Hochberg method. ................................................................. 120

Table 6.3. P values derived from comparisons of means between the Eastern, Southern, and Western Lapita sample groups using ANCOVA. Asterisk indicates statistical significance at $\alpha=0.05$. ............. 121

Table 6.4. Post-hoc comparisons of attribute distribution between Lapita samples in the Eastern, Western, and Southern Provinces. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical $p$ values. Statistical significance is determined at different $\alpha$ values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The $\alpha$ values were determined using the Benjamini-Hochberg method. ......................................................... 123

Table 6.5. P values derived from comparisons of means between the Eastern, Southern, and Western Lapita sample groups using ANCOVA. Asterisk indicates statistical significance at $\alpha=0.05$. ............. 125

Table 6.6. Post-hoc comparisons of attribute distribution between Lapita samples from the Eastern, Western, and Southern Provinces. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical $p$ values. Statistical significance is determined at different $\alpha$ values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The $\alpha$ values were determined using the Benjamini-Hochberg method. ......................................................... 127

Table 6.7. P values derived from Fischer’s Exact test to determine the significance of association between attributes and ceramic sherds from the Eastern, Southern, and Western Lapita sample groups. Asterisk indicates statistical significance at $\alpha = 0.05$. ......................... 129

Table 6.8. Post-hoc comparisons of categorical attributes between Lapita samples from the Eastern, Western, and Southern Provinces. The $\alpha$ value was determined using the Benjamini-Hochberg method and is indicated after the attribute name. ......................................................... 131
Table 6.9.  P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with element, motif, and process attributes for the six Lapita samples. Significance is denoted by asterisk. Significance indicates that dentate density, sherd width, and sherd length are significant predictors of attributes and must be controlled for in subsequent analysis.

Table 6.10.  Post-hoc comparisons resulting from individual Fischer's Exact tests between sample groups from the Eastern, Western, and Southern Lapita Provinces. The α value was determined using the Benjamini-Hochberg method and is provided after the attribute name.

Table 6.11.  Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. The element symbol refers to the updated Chiu and Sand (2005) code presented in Table 4.2.

Table 6.12.  Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system.

Table 6.13.  Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. The process symbol refers to those used in the Sharp (1988) system.

Table 7.1.  P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 attributes for Tongan Lapita samples. Significance is denoted by asterisk and determined at an α level of 0.05.

Table 7.2.  Post-hoc comparisons of dentate density distribution between four Tongan Lapita samples. Chart indicates which groups differ significantly by indication of statistical p values. Statistical significance is determined at an α level calculated using the Benjamini-Hochberg Method.

Table 7.3.  P values derived from comparisons of means between the four Tongan Lapita sample groups using ANCOVA. Asterisk indicates statistical significant at an α level of 0.05.

Table 7.4.  Post-hoc comparisons of width distribution between four Lapita samples. Statistical significance is determined at different α levels depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The α values were determined using the Benjamini-Hochberg method.
Table 7.5. P values derived from Fischer's Exact test to determine the significance of association between attributes and ceramic sherds from Tongan Lapita sample groups. Asterisk indicates statistical significance at an $\alpha$ value of 0.05. .................................................. 155

Table 7.6. Post-hoc comparisons of zone direction between four Tongan Lapita samples through individual Fischer's Exact tests. Chart indicates which groups differ significantly by indication of statistical $p$ values. Statistical significance is determined at an $\alpha$ level calculated using the Benjamini-Hochberg Method. ............................................. 155

Table 7.7. P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with element/motif/process attributes for Tongan Lapita samples. Significance is determined at an $\alpha$ level of 0.05 and is denoted by an asterisk. ........................................................................... 156

Table 7.8. Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. Element code refers to the updated Chiu and Sand (2005) system presented in Chapter 4. ........................................................................... 160

Table 7.9. Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system. ........................................................................... 162

Table 7.10. Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. The process symbol refers to those used in the Sharp (1988) system. ....................... 162
List of Figures

Figure 1.1. Dentate-stamped Lapita pottery. Arrows indicate shape of dentate tool application. Ceramic sherd K1-5 from Kavewa, Fiji. ........................... 2

Figure 1.2. Example of a Lapita pot from Vorovoro, Fiji. The design field has been organized into design zones through horizontally spaced dentate-stamped lines. Illustration by Vienna Chichi Lam. ........................... 3

Figure 1.3. Map of the Lapita range in Oceania as indicated by lighter shaded region. Areas enclosed by a dash indicate Lapita Provinces. Note that the “South Papuan Lapita Province” is newly discovered and, as such, represents a hypothesis of known ceramic distribution rather than a cohesive stylistic ceramic tradition (David et al. 2011). The Solomon Islands Lapita distribution is also questionable, but Late Lapita ceramic sherds have been found in the circled region (Sheppard 2011). Map adapted from David et al. with permission (2011:578). ........................................ 4

Figure 1.4. Island groups included in the Eastern Lapita Province. Arrows indicate archaeological sites analyzed in this dissertation. Map by Vienna Chichi Lam. ................................................................. 5

Figure 4.1. Images taken from ceramic sherd K1-5 from Kavewa, Fiji. Magnified with the Leica MZ6 stereomicroscope. Image on top magnified 6.3x and image on bottom magnified 25x. Image on the top shows a 1cm² square used to measure dentate density. Image on the bottom indicates spacing measurements (small orange arrows represent spacing 1, large orange arrow represents spacing 2) and dentate length/width measurements (red arrows). ........ 75

Figure 4.2. Image provided by the Olympus LEXT 4000 laser scanning confocal microscope of ceramic sherd K1-5 from Kavewa, Fiji at a magnification of 108x. Arrows represent length (horizontal) and width (vertical) measurements of a single dentate tooth impression. ........................................... 77

Figure 4.3. Image provided by Olympus LEXT 4000 of ceramic sherd Voro10:191 from Vorovo, Fiji magnified at 108x. Colours represent differential depth measurements, which can be accurately measured through the corresponding software, as seen in the bottom left corner. ................................................................. 78

Figure 4.4. Image provided by Olympus LEXT 4000 of ceramic sherd To2-2749 from Nukuleka, Tonga. Through corresponding software, the area, surface area, and volume of a given dentate-stamped tooth can be measured as shown in the bottom left corner. .............................. 79
Figure 4.5. Photo of ceramic sherd from the Lapita site in New Caledonia. Orange arrow indicates the process of half-drop mesh, while the red arrow represent the process of repetition. Both also represent the process of intersection because there is no visible space between elements. ................................................................. 84

Figure 4.6. Photo of ceramic sherd 221 from the Lapita site in New Caledonia. The design zone is separated into two horizontal zones through the use of a single horizontal dentate-stamped line as indicated by the arrow. ................................................................. 85

Figure 5.1. Island groups included in the Eastern Lapita Province. Arrows indicate archaeological sites analyzed in this study. Map by Vienna Chichi Lam. ................................................................. 91

Figure 5.2. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Island group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji. ................................................................. 97

Figure 5.3. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji. 100

Figure 5.4. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji. 100

Figure 5.5. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji. 101

Figure 5.6. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji. 103
Figure 5.7. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

Figure 5.8. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

Figure 5.9. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, and sample 4 represents East Fiji.

Figure 5.10. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, and sample 4 represents East Fiji.

Figure 6.1. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

Figure 6.2. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.
Figure 6.3. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu. 124

Figure 6.4. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu. 124

Figure 6.5. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu. 128

Figure 6.6. Least squares means plot for dentate area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu. 128

Figure 6.7. Least squares means plot for dentate surface area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu. 129

Figure 6.8. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Element code refers to that shown in Table 4.2. 135
Figure 6.9. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Motif code refers to that in Poulsen (1987), Mead et al. (1975), and Anson (1981). .......................................................... 136

Figure 6.10. Mosaic plot of process frequency by sample group. The vertical length of each rectangle is proportional to the proportions of process type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each process type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Process code refers to that found in Sharp (1988). ............ 137

Figure 7.1. Island groups in the Tongan archipelago. Archaeological sites sampled from the island groups of Tongatapu, Ha’apai, and Vava’u in this case study are outlined. ...................................................... 148

Figure 7.2. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho............................................................... 152

Figure 7.3. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. .................................................................................. 154

Figure 7.4. Least squares means plot for dentate surface area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, and sample 7 represents Vava’u................................................. 154

Figure 7.5. Least squares means plot for the number of processes per shed. The means are estimated from a linear model and adjusted for the covariate of dentate density, sherd length, and sherd width. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho................................................. 156
Figure 7.6. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. Element code refers to that in Table 4.2.

Figure 7.7. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. Motif code refers to that outlined in Chapter 4.

Figure 7.8. Mosaic plot of process frequency by sample group. The vertical length of each rectangle is proportional to the proportions of process type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each process type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. Process code refers to that outlined in Sharp (1988).
Chapter 1.

Introduction to Lapita Ceramic Design Analysis

Lapita represents a “cultural complex” (Green 1979) of an assumed genetic and linguistically distinct group of people in Near and Remote Oceania, marking the final chapter of human Neolithic expansion (Kirch 1997, 2010). Largely recognized by the first appearance of pottery in the Bismarck Archipelago, Lapita is associated with a shift in settlement and subsistence practice around 2400-3200 BP (Denham et al. 2012; Kirch 1997). Within 200-400 years of the first appearance of Lapita pottery in the Bismarcks, the Lapita expansion crossed into Remote Oceania and reached its furthest eastern extent by 2800 BP: the Fiji, Tonga, and Samoa island groups in the southwest Pacific (Burley et al. 2015; Denham et al. 2012; Kirch 2010; Martinsson-Wallin 2007; Petchey et al. 2016). Similarity in ceramic design motifs within the latter region has led to its demarcation as the “Eastern Lapita Province”, a region where interaction among potters is assumed to have taken place following initial colonization (Clark and Murray 2006; Green 1979; Kirch 1997). While this hypothesis may hold true, recent observations have suggested that the structural execution and layout of design elements and motifs differ throughout this region (Burley et al. 2002; Burley and LeBlanc 2015). An analytical approach required to quantify and compare this variation is currently lacking. For this reason, a new approach focused on the structural application of Lapita ceramic design is developed here and used to test patterns of similarity/dissimilarity in design throughout the Eastern Lapita Province and beyond.

Ceramic design analysis has played an important role in the field of Lapita archaeology since the 1960s, with ceramics forming the bulk of assemblages. Designs were created using variably sized straight, curved, or circular comb-like tooth stamps, referred to as dentate (Ambrose 2003; Siorat 1990) (Fig. 1.1). Each stamp produced a design element; elements were combined in highly regularized ways to form design
motifs and fields (Mead et al. 1975; Sharp 1988) (Fig. 1.2). Design motifs have become an important diagnostic tool, widely used to test hypotheses of interaction and migration throughout the Lapita past and to identify regions of stylistic homogeneity, referred to as “provinces” (Green 1979; Kirch 1997) (Fig. 1.3).

Figure 1.1. Dentate-stamped Lapita pottery. Arrows indicate shape of dentate tool application. Ceramic sherd K1-5 from Kavewa, Fiji.

Dentate stamp design analysis has been largely focused on identifying elements – “a decorative unit executed by one single act” (Chiu 2003:226) - and motifs - “the succession of one design element, used as a fixed set to be combined with other design elements…” (Chiu and Sand 2005:138). However, the lack of a large-scale database to standardize and compare design, as is now being developed by Chiu and Sand (2005), and a lack of smaller-scale approaches capable of analyzing design size and application, has brought about confusion surrounding design classification and comparison (Burley and LeBlanc 2015; Chiu and Sand 2005; Cochrane and Lipo 2010). This dissertation attempts to address this issue, in part, by developing a new approach to Lapita ceramic design analysis, focused on quantifying the structural layout and application of design.
Figure 1.2. Example of a Lapita pot from Vorovoro, Fiji. The design field has been organized into design zones through horizontally spaced dentate-stamped lines. Illustration by Vienna Chichi Lam.
The structural approach will be applied within a cultural transmission framework, acknowledging the importance and predictions of the transmission process to design replication. Several ceramic ethnoarchaeological studies have alerted archaeologists to the processes at play during the transmission of ceramic design (Bowser 2000; Chernela 2008; Degoy 2008; Friedrich 1970; Gosselain 2008; Herbich 1987; Wallaert 2008).
Preliminary results suggest that elements/motifs are passed on within and between generations through different transmission mechanisms than those through which structural attributes are learned. Such results question the utility of relying solely on one form of design to answer larger questions of social interaction. While similarity in elements/motifs throughout a region *could* signal interaction, it could equally reflect recent common ancestry. Consistency in the application of structural aspects of design, on the other hand, likely required more intensive interaction between potting communities (Friedrich 1970).

Figure 1.4. Island groups included in the Eastern Lapita Province. Arrows indicate archaeological sites analyzed in this dissertation. Map by Vienna Chichi Lam.

Based on the above observations, structural ceramic design analysis will be employed here using the Eastern Lapita Province as a pilot study to measure patterns of design execution and to compare results to patterns provided by the analysis of design elements/motifs. This is a region where migration and interaction are hotly debated (Burley and LeBlanc 2015; Clark and Anderson 2009; Clark and Murray 2006). A data set from beyond this region, in the western and southern Lapita sphere, will be used as
out-group samples. The data set will be analyzed to test hypotheses regarding interaction, using both the new structural approach, as well as the element/motif approach. If results derived from the approaches differ, it may suggest that these two aspects of design have different transmission histories. The central premise of this research is that the ways in which potters place elements/motifs and structural aspects of design onto a pot vary. It is this variation I aim to measure.

Recent advances in microscopy allow for more accurate measurement of design on sherds once considered too small for structural analysis (Artal-Isbrand et al. 2011; Artal-Isbrand and Klausmeyer 2013; Canouts 1991). Illuminated light stereomicroscopy and laser scanning confocal microscopy are utilized here to measure the spacing, density, and size of dentate application. This technology is particularly suited for measuring Lapita pottery, where most designs are impressed onto the vessel surface. The overall aim of developing a structural approach to Lapita design analysis is threefold: (1) to provide a more objective measure of design variation, (2) to provide an approach that is applicable across the Lapita range, both temporally and geographically, and (3) to question the theoretical emphasis placed on elements/motifs for understanding patterns of design transmission. Ultimately, this study will require Lapita archaeologists to reflect on the tool they have relied upon for so long – ceramic design – and to critically reconsider how we analyze design and what questions we wish to ask of the approach.

1.1. Ceramic Design Analysis in the Context of Lapita Archaeology

The first attempt to make analytical comparisons between Lapita designs was undertaken by Golson (1972) in the late 1960s (Green 1990). Early studies focused for the most part on identification of elements and motifs. In 1967, Poulsen’s (1987) dissertation became one of the first studies to compile a motif list. The code was based on ceramics excavated from six Lapita sites on the Tongan island of Tongatapu. Poulsen’s (1987) system also made note of the vessel type and place of decoration on the pot. While an important early step in the analysis of Lapita design, Poulsen’s system remained largely inapplicable beyond the Tongan Lapita sphere (Green 1990:34).
Poulsen’s approach in Tonga was soon followed by Mead’s (1975) attempt to develop a semiotic structural approach focusing on the process rules of motif application with the aim of developing a “grammar” of Lapita design. This required scholars to identify the predominant processes by which motifs were placed onto a vessel surface and provide a rule for the process and direction of application. Mead and colleagues (1975) were also instrumental in developing an element and motif inventory for the Eastern Lapita region. The Mead system was applied by several scholars (Donovan 1973; Kirch 1981; Sharp 1988), including Sharp (1988) who systematically analyzed the process rules behind which design elements were combined to form more complex motifs.

Despite the several important attempts to analyze Lapita design, the structural semiotic system fell out of practice and was replaced by the element/motif approach (Green 1990). This was, in part, due to the work of Anson (1983) in his analysis of Lapita pottery from the Bismarck Archipelago. Noting that the semiotic system did not allow for immediate calculation of motif frequency, Anson (1983) chose to list motifs and their variations based on visual inspection without consideration of design structure (Chiu and Sand 2005). Based on the reasoning that Mead’s categories of design, or motifs, were subjective, Anson (1983) broke down motif categories into “very restricted decorative unit categories,” referred to as alloforms (1983:59). Although still subjective in nature, the motif categories mirrored, to as specific an extent as possible, the designs visible on ceramic sherds. The number of known Lapita motifs expanded from a little over 100, to over 500, making any meaningful comparison of design rules difficult, if not pointless (Green 1990:41).

Following from Anson (1983), the most current and common method for analyzing Lapita design is to tabulate the number and category of elements/motifs within a given ceramic assemblage and to subsequently compare either the presence/absence or frequency using simple matching coefficients (i.e. Jaccard, Robinson). These methods, along with a comparison of vessel form and non-ceramic material culture, have led to the demarcation of Lapita “Provinces”, areas of perceived stylistic similarity. There currently exist five Lapita Provinces: Far Western, Western, Southern, Eastern, and South Papuan (Anson 1983; Best 1984; McNiven et al. 2011; Sand 2001; Summerhayes
Stylistic variation between the provinces is used to infer hypotheses of Lapita interaction and migration.

1.2. Lapita Ceramic Design Methods: The Problem

The above methods have led to a series of element/motif inventories, not widely applicable across Lapita ceramic assemblages (Chiu and Sand 2005). As a result, scholars often choose one inventory and add changes to suit their particular ceramic assemblage and associated Lapita province (Bedford 2006; Best 1984; Burley et al. 2002; Clark and Murray 2006). This has also led to duplication of and confusion surrounding motif labels (Green 1990). A review of the literature indicates that the motif lists compiled by Mead (1975), Anson (1983), and Poulsen (1987) are most widely used, depending on the region investigated. The result is a non-cohesive literature of Lapita design analysis with contradictory interpretations of Lapita interaction.

Aside from issues with classification, the element/motif approach has been cited as a subjective process outside of the Lapita realm (Arnold 1983; Jernigan 1986; Plog 1980). This is due to the absence of objective criteria and protocol for determining the shape, size, and design of a motif. In other words, it is not possible to understand what potters conceived of as discrete decorative units. Despite this, the approach is often advocated as being the only appropriate method available when small sherds comprise the bulk of a ceramic assemblage (Canouts 1991). In contrast, when larger sherds are available, structural approaches to design analysis are often used. Structural approaches focus on organization (Canouts 1991; Hardin 1983; Hegmon 1994, 1995), which refers to “layout, symmetry, and the use of elements in particular contexts or combinations” (Hegmon 1995:157). Cross-cultural studies of ceramic design (Canouts 1991; Friedrich 1970; Hardin 1983; Hardin and Mills 2000; Hegmon 1995; Washburn and Crowe 1988, 2004) have suggested that analysis of design structure offers a better way for understanding communication and interaction within and between groups, as it resists diffusion more easily than design elements/motifs. This is due to the hypothesis that potters need to be instructed on how to apply design, while elements and motifs can be easily copied from sight. While both approaches have applicability in Lapita design analysis (Chiu and Sand 2005), it is the element/motif approach that dominates, often
without critical analysis of the extent to which the two approaches are appropriate for the questions asked.

Regardless of the question surrounding which method is more appropriate, the element/motif approach in Lapita archaeology masks the complexity with which elements/motifs are applied to a vessel surface. While several different archaeological assemblages within the Lapita range share similar motifs, the density with which the motifs are applied vary widely. This difference in motif application has been noted by several Lapita archaeologists (Burley et al. 2002; Chiu and Sand 2005; Clark and Anderson 2009; Cochrane and Lipo 2010), but has not yet been quantified.

Despite the lack of structural analysis, several Lapita scholars have suggested potential structural methods. Chiu and Sand (2005) emphasize a multi-factor approach and a revival of structural analysis for Lapita ceramics, combining several of the above-mentioned systems, along with symmetry analysis (see Washburn and Crowe 1988, 2004) and comparisons between design fields and vessel shapes. The Chiu and Sand (2005) approach, while a step in the right direction, still falls short in terms of widespread applicability across the Lapita range, as it focuses primarily on New Caledonian Lapita designs, and anthropomorphic motifs in particular. A new approach to design analysis by Carson and colleagues (2013) attempts to analyze not just design motifs, but also tool use and application. This approach seems profitable, but lacks detail and a standardized methodology required for regional applicability. Neither approach quantifies, with any objective replicability, the complexity of design. Nevertheless, the above studies have set the foundation for a critical appraisal of Lapita design analysis.

Along with the lack of structural methods, there is a lack of theorizing on which aspects of design signal information and how that information is passed within and between generations. The ways in which potters learn to create design and apply it to ceramic vessels is of the utmost importance for understanding patterns of interaction. Ethnographic work on ceramic design carried out in Mexico in the late 1960s by Friedrich (1970) alerted archaeologists to aspects of decorative style that signal intense communication between potters. She found that, contrary to popular belief, it was not decorative elements or motifs that indicate potter interaction and communication, but,
rather, structural aspects of decoration. The most important of these structural features include those that resist diffusion and therefore signal intense interaction: “1) organization of spatial divisions, 2) classification of design configurations, and 3) function of design elements in the configurations in which they occur” (Friedrich 1970:338). Despite this early suggestion that element/motifs and structural aspects of design are passed between generations by different mechanisms, little comparative analysis of these two aspects of design has come about, both within Lapita archaeology and cross-culturally.

A cultural transmission perspective provides a useful theoretical framework from which to understand patterns of design diversity and homogeneity throughout space and time. Cultural transmission (CT) theory refers to the transfer of cultural traits between individuals. CT theory views human culture as an inheritance system, aiming to identify the processes through which cultural traits are passed between individuals and to explain resulting population-level patterns (Richerson and Boyd 2005; Shennan 2002). Predictions derived from this theoretical framework can be used to determine mechanisms of interaction both within and between groups, questions that are of particular importance to Lapita archaeology. While CT studies of Lapita design have been undertaken (ex. Clark and Murray 2006; Cochrane and Lipo 2010), they have relied upon the element/motif approach of ceramic design analysis, to the exclusion of structural methods. Throughout this dissertation, I address this gap and theorize that the mechanisms through which elements/motifs and structural aspects of design are passed within and between generations during the Lapita period differ as predicted by CT theory.

The field of Lapita design analysis has progressed tremendously since early recognition of design similarity, with conference proceedings devoted to discussion on the topic (Sand et al. 2015; Spriggs 1990) and a Lapita design database in construction (Chiu and Sand 2005). It is now time to critically reflect on the utility of the element/motif approach alongside structural alternatives and to acknowledge the complexity of transmission mechanisms leading to the intricacy of Lapita design.
1.3. A New Structural Approach to Lapita Ceramic Design Analysis

A structural approach has been previously proposed for Lapita ceramic analysis (see Chiu and Sand 2005), albeit with little follow-up or examples of its application. My aim will be to build on the structural approach of Chiu and Sand (2005), by taking design characters that can be quantified such as dentate density, dentate width/spacing, dentate surface area, dentate volume, and use these to answer questions of interaction within and between regions during the Lapita period.

In order to carry out the structural approach, I employ the use of microscopy techniques. Specifically, I use incident light illumination and laser scanning confocal microscopy, the latter being capable of 3D imaging. These instruments allow for accuracy and precision in measuring the complexity of dentate application. This approach will be applicable for both large and small ceramic sherds, ensuring widespread applicability for Lapita ceramic design analysis.

The element/motif approach will be carried out alongside the structural approach on the same data set in order to test the following null hypothesis:

*The ways in which decorative ceramic design is classified into attributes does not impact the conclusions reached about Lapita archaeology when different attributes are compared.*

This hypothesis will be tested by analyzing a data set from the Eastern Lapita Province, and comparing it to out-group ceramic assemblages from the Western and Southern Lapita Provinces.

1.4. Case Studies

Application of the structural approach to Lapita ceramic design analysis will be demonstrated through three case studies. The first will focus on the Eastern Lapita Province in order to determine if design characters are similar enough to suggest that
this region be considered a cohesive interaction sphere. In particular, structural and element/motif attributes throughout this region will be compared to determine if both suggest similar conclusions regarding homogeneity/diversity in design type and application. The second case study will expand the study region to include samples from provinces outside of the Eastern Lapita range. Comparison of design characters within and between regions will provide an additional line of evidence to evaluate the cohesiveness of the Eastern Lapita Province designation. The third and final case study will take a more in-depth look at design within the Eastern Lapita Province and within Tonga specifically. Precise dating of this region (Burley et al. 2015) enables comparison of design type and application on a time scale not possible in any other region within the Eastern Lapita Province; thereby, providing a rare glimpse into design homogeneity/diversity within a few generations. An overview of each case study, along with motivations for undertaking each, is provided below.

1.4.1. Case Study 1: The Eastern Lapita Province

On the basis of similarity in ceramic form and element/motif repertoire, the Eastern Lapita Province was originally taken to include West Fiji, Lau (East Fiji), Tonga and Niuatoputapu (a northern Tongan outlier), Samoa, ‘Uvea, and East Futuna (Green 1979; Kirch 1981, 1988a; Sand 1996). Green (1979:42) was the first to find support for a distinct Eastern Lapita region, confirming an “overall west-to-east trend indicative of distance decay,” where Eastern Lapita design was “more simplified and generally rectilinear” as opposed to the “rather ornate curvilinear and fairly elaborate rectilinear” designs of Western Lapita. He came to this conclusion based on a comparison of the presence/absence of ceramic design motifs in an ordered matrix of Jaccard coefficients.

A recent re-evaluation of the Eastern Lapita classification by Burley and LeBlanc (2015) suggests that the grouping of diverse regions under “Eastern Lapita” ignores underlying patterns of interaction and exchange. For example, several sites in Fiji,
including the earliest dated sites of Bourewa¹ and Vorovoro, have ceramic assemblages characteristic of the Western Lapita Province (Burley 2012; Nunn 2007; Nunn et al. 2007), as do several other Lapita sites in Fiji including Natunuku, Yanuca, Naigani and Naitabale (Irwin et al. 2011; Nunn et al. 2007). In Tonga, ceramic assemblages at the earliest dated site of Nukuleka again show several similarities with Western Lapita assemblages. In contrast to the pattern in Fiji, similarities end shortly after initial landfall, as demonstrated by simplification in ceramic form and design (Burley and Dickinson 2010; Burley et al. 2002; Burley 2012). Ultimately, Burley and LeBlanc (2015) conclude that the categorization of Eastern Lapita does not adequately reflect exchange and interaction patterns known from archaeological or linguistic evidence.

Much of the debate centers around the evidence for West Fiji, East Fiji (Lau), and Tonga, in particular (Burley 2013; Burley and LeBlanc 2015; Clark and Murray 2006; Cochrane and Lipo 2010). Archaeological ceramic evidence of the Lapita sequence in East Fiji appears to mirror that of Tonga, suggesting that colonizers in East Fiji originated from, or at least interacted with, Tonga (Best 1984; Burley 2013). Linguistic evidence provides further support for the hypothesis that East Fiji was settled from and/or interacted with Tonga during the Lapita period (Geraghty 1983). Historical linguist Paul Geraghty (1983) suggests that East Fijian languages of Lau correspond to the Proto Tokalau Fijian language family, a sub-group of Proto Central Pacific that includes Tonga, Samoa, and Lau, to the exclusion of West Fiji, save for the southeastern coast of Vanua Levu. Burley (2013) takes this as support for separate west and east interaction spheres for the Lapita period, the latter comprised of Lau, Tonga and Samoa, the former comprised of West Fiji.

The analysis of ceramic elements/motifs, however, provides contradictory results to questions of migration and interaction in the Eastern Lapita Province. Best's (1984) use of the Robinson and Jaccard coefficient to analyze the frequency and presence/absence of design motifs, indicates greater similarity between Lau and Tonga, than West Fiji. The most recent analysis of the presence/absence and frequency of

¹ See Nunn and Petchy (2013) for a recent re-evaluation of radiocarbon dates for Bourewa that questions its antiquity. Here, I identify Bourewa as a potential founder settlement based on western Lapita style ceramic design and its position on the southwestern coast of Viti Levu.
ceramic decorative elements/motifs, however, appears to contradict this patterning and
instead suggests that Lau was settled from and interacted with both West Fiji and Tonga
during the Lapita period through predominately peer-to-peer transmission (Clark and
Murray 2006; Cochrane and Lipo 2010).

It is clear that, even to an untrained eye, the spatial application of ceramic design
differs between West Fiji, Lau, and Tonga (Burley et al. 2002; Burley and LeBlanc 2015).
Despite this observation, there has not, as of yet, been an objective way to measure and
compare this variation. The structural approach will address this gap. In fact, most
studies of ceramic design from this region have compared either presence/absence or
frequency of elements/motifs. I, too, will analyze these attributes. However, incorporating
structural design characters into the analysis will enable the element/motif approach to
be critically compared.

Several motifs throughout this region are shared with Lapita Provinces to the
west (Summerhayes 2000a). Basing comparisons on motifs alone, masks structural
aspects of design variability. The new structural approach will be used to analyze
ceramic samples from four Lapita groups in the Eastern Lapita Province: Early Tonga,
Late Tonga, West Fiji, and Lau. The Eastern Lapita Province is organized into these
categories in order to analyze both spatial and temporal homogeneity/heterogeneity.

1.4.2. Case Study 2: A View from Outside

In order to determine if ceramic design variability, or lack thereof, in the Eastern
Lapita Province is characteristic of the region or is shared more broadly throughout the
Lapita range, I will compare ceramic samples from both the Southern and Western
Lapita Provinces to the data set outlined above. The Lapita Provinces have been
characterized predominantly based on regional similarity in ceramic design, vessel form,
and obsidian and adze distribution, among other non-ceramic attributes. Based on these
characteristics, regions of similarity have been grouped together under the umbrella term
of “province”. Although there is some disagreement over whether the similarity within
groups represents regional boundaries, or, is instead, a product of temporal variation
(Summerhayes 2000a,b, 2010), consensus seems to rest on the utility of the regional province classification system for demarcating variation in Lapita characteristics.

Observation of ceramic design density and the analysis of design element/motifs in particular, has led to the hypothesis that more densely applied and intricate dentate designs appear early in the western sphere and subsequently decrease as Lapita potters move eastward. The least densely applied and simplest motif repertoire is attributed to the later arrival of Lapita peoples in the Eastern Lapita Province. If this holds true, then measureable attributes of dentate density and size/shape, should differ between the three provinces. If Eastern Lapita represents a distinct regional boundary, then variation within this region should be less than variation between regions. I will test this using both the element/motif and structural approach. The structural approach will be able to identify patterning in design density and layout, characteristics that have not yet been used to test variation within and between Lapita provinces.

1.4.3. Case Study 3: A View from Within

The structural approach will also be used to address questions related to interaction between potters throughout Tonga in the Lapita period. Well-dated assemblages from multiple islands and time periods in the archipelago are available and will be analyzed to understand change in ceramic design through time. One of the major questions left unanswered in Tongan Lapita archaeology is the reason for homogeneity in ceramic design and subsequent loss of design throughout the archipelago. An understanding of design change through time, both within and between islands in Tonga, will help to answer this.

The Nukuleka site on the island of Tongatapu has been recognized as the likely founder settlement for Lapita peoples in Tonga (Burley and Dickinson 2001, 2010). Ceramic assemblages from Nukuleka have markers indicative of “Western Lapita” style in the earliest layers (Burley et al. 2002), along with non-local paste characteristics (Burley and Dickinson 2010). Through time, western motifs and structural application are lost and design is simplified and expanded (Burley et al. 2002). Settlements north of Tongatapu do not appear to share western motif variants or non-local paste (Burley and
Dickinson 2010). Less than two centuries after first human arrival in Tonga, design is lost from the ceramic repertoire altogether (Burley et al. 2015). Comparison of motif and structural attributes between Nukuleka and assemblages further north, will be used to identify the patterns of design change that take place during this transitional period.

1.5. Organization of Dissertation

In this chapter I have introduced the research problem and study objectives, provided a brief outline of the research field, and have described my research methods and preliminary hypotheses for three case studies. In Chapter 2, I will provide extensive background on the field of Lapita archaeology, within the context of ceramic design analysis. I will also provide background on use of ceramic design methods in cross-cultural study areas. Chapter 2 will define the context for developing a structural approach to Lapita ceramic design analysis.

The theoretical framework for the development of the structural approach is outlined in Chapter 3. After a description of my theoretical focus, I present the derived hypotheses and predictions for each of the three study cases. My methodology is discussed in Chapter 4. Here, I outline, in detail, my newly proposed structural approach to Lapita design analysis, including qualitative and quantitative attributes, microscopy techniques, and statistical testing procedures for evaluating homogeneity and/or heterogeneity in design application between the study regions. The following three chapters are organized by case study. Chapter 5, 6, and 7 present the methods, results, and discussion for Case Studies 1, 2, and 3, respectively.

My final chapter presents the discussion and conclusion. In Chapter 8 I compare the results of the structural approach to those garnered from the element/motif approach. The new “shape” of the Eastern Lapita Province is outlined in comparison to the Southern and Western Lapita Provinces as they pertain to results from the structural approach. Comparison with earlier studies of ceramic design within the Eastern Lapita Province is then undertaken, with a discussion of potential theoretical reasons for similarity and difference. Chapter 8 concludes with a discussion of the impact of the
structural approach to Lapita ceramic design analysis and a suggestion of where the field should progress from here.
Chapter 2.

Context for the Development of a Structural Approach to Lapita Ceramic Design Analysis

Lapita pottery was first discovered by Father Otto Meyer in 1908 at Rakival Village on Watom Island in the Bismarck Archipelago. However, it was not until 1950 that these highly distinct and predominately dentate-stamped decorated ceramics were given the name “Lapita” by Gifford and Shutler (1956) after the excavation of type Site 13A in New Caledonia. Homogeneity in both decorative and technological attributes of Lapita ceramics across the geographic divide of Melanesia/Polynesia, was first identified in the 1960s by Golsen (1961), suggesting that there once existed a cohesive culture spanning this region. Along with ceramics, similarity in subsistence, settlement pattern and non-ceramic material culture, led Green (1979:34) to propose the term “Lapita Cultural Complex” to underscore this set of archaeological characteristics as both a horizon and a tradition.

Since demarcation of Lapita as a “cultural complex”, several hypotheses have been put forward to explain details of its hypothesized origin in the Bismarck Archipelago. The “fast-train” hypothesis posits that Lapita represents the eastward movement of a culturally distinct group(s) of people into the Bismarcks who interact to a very limited degree, if at all, with indigenous groups before rapidly moving east into Remote Oceania (Kirch 1997). Evidence for this model largely comes from genetic (i.e. Friedlaender et al. 2008) and linguistic (i.e. Gray et al. 2009; Greenhill et al. 2010) studies. A second, but related model, termed the “slow-boat”, again views Lapita as a distinct group of people entering the Bismarcks from somewhere in Island Southeast Asia, but, in contrast, suggests that Lapita groups spent a considerable amount of time in the Bismarck region, interacting with local groups, before heading east (Kirch 1997). Genetic studies lend support to this model (i.e. Kayser et al. 2006; Wollstein et al. 2010),
as does most archaeological evidence (Allen and Gosden, eds., 1991) and Bayesian approaches to radiocarbon dating in the region (Denham et al. 2012). The third model, referred to as the “Entangled Bank” hypothesis, suggests that Lapita arose in the Bismarcks with little to no influence of migration from Island Southeast Asia. This model has gained little support from archaeological, genetic, and linguistic evidence (aside from Soares et al. 2011; White et al. 1988). Others (Terrell 2003, 2010; Terrell et al. 2001) do not view Lapita as a cohesive cultural unit, but rather as “a nucleus of associated traits that diffused from one community to another…” (Terrell 2003). Despite such varying views, a review of the literature clearly suggests consensus surrounding the notion of Lapita not only as a cultural complex, but as a product of the intrusion of migrants into the Bismarcks and integration with indigenous inhabitants (Green 1991). This interaction led to the innovation of intricately decorated dentate stamped ceramics that are currently associated with the Lapita cultural complex.

Genetic studies are beginning to provide a more clear picture of interaction before and during the Lapita period. Kayser and colleagues (2006) investigate non-recombining portions of the Y chromosome (NRY) along with mitochondrial DNA (mtDNA) markers to understand the genetic origin of Polynesians. Assuming that present-day Polynesians represent direct descendants of the Lapita migration throughout the South Pacific, and using a sample size of 400 individuals from eight different islands throughout Oceania, Australia and East Asia, they attribute 68.5% of Polynesian NRY chromosomes to a Melanesian origin and 28.3% to an Asian origin. In contrast, 93.8% of Polynesian mtDNA are of Asian origin and only 6% are attributed to a Melanesian source (Kayser et al. 2006). Given these results, Kayser and colleagues (2006) argue for a “dual genetic heritage” model of Polynesian ancestry, suggestive of interaction within the Bismarck archipelago of at least two genetically distinct groups. Similarly, Wollstein and colleagues (2010), using single nucleotide polymorphisms (SNPs) from individuals in Polynesia, Fiji, Highland New Guinea and Borneo, demonstrate that Polynesian samples represent a genetically admixed population with ancestry components derived from both East Asia and Near Oceania. They date this potential admixture to 3 kya (Wollstein et al. 2010:1987) and take the results as further evidence for the slow-boat model, given that Polynesia samples appear to result from a
period of Asian and Melanesian admixture before migration into Remote Oceania (Wollstein et al. 2010).

The fast-train model has also garnered support from genetic studies. Friedlaender and colleagues (2008) assess autosomal genetic markers from 952 individuals from 41 Pacific populations including the Bismarcks, New Guinea, Micronesia, Polynesia and Taiwan. Structure analysis suggests that Polynesian samples are more related to Taiwan aboriginal samples than to those from Europe or the Bismarcks (Friedlaender et al. 2008). Given the apparent lack of genetic contribution from the Bismarcks to present-day Polynesian samples, Friedlaender and colleagues (2008) argue for a rapid expansion of individuals, likely originating from Taiwan, across the Near/Remote Oceanian border, traveling on a “fast-train”.

Results from linguistic models appear to support the fast-train model, while at the same time reconfirming the notion of an “out-of-Taiwan” migration of Austronesian speakers into Island Melanesia at about the same time as the earliest archaeological evidence for Lapita in the Bismarcks. Using Bayesian phylogenetic methods derived from evolutionary biology, Gray and colleagues (2009) determine that Formosan languages of Taiwan are ancestral to the Austronesian language family, a sub-branch of which is associated with Lapita (Kirch 1997; Ross et al. 1988). The branching structure of linguistic phylogenetic trees suggests evidence for long pauses, followed by rapid expansion of Austronesian groups (Gray et al. 2009). Two major pauses in particular are suggested, one in the Philippines around 3800-4500 BP and a second one in western Polynesian around 2800 BP. Pauses are followed by increased language diversification rates, indicating a “pulse” of rapid expansion (Gray et al. 2009). Given the lack of evidence for a linguistic pause in the Bismarck region at around the time of Lapita emergence, Gray and colleagues (2009) argue against the slow-boat model, opting for a “pulse-pause” model of Austronesian migration. A follow-up study by the same authors (Greenhill et al. 2010) reconfirms their initial results.

A recent archaeological study of ceramic data from Southeast Asia, particularly the Philippines and Mariana Islands, compares sherds to Lapita ceramics in the Bismarck archipelago in an attempt to identify the route taken by Lapita ancestors
(Carson et al. 2013). Results indicate astounding similarities between the three regions in terms of use of red slip, ceramic vessel form, placement of decoration, decorative techniques and tools, and motifs, especially with respect to early Lapita ceramics, suggesting evidence of intrusion, integration, and innovation (Green 1991) in the Bismarck “homeland”. In particular, similarity in red slip, lime-infill, circle-stamping, point impression, horizontal zoning, and rectilinear motifs is taken as evidence for intrusion of a new group of people into the Bismarcks. Integration is argued based on an elaborated tool-kit and motifs. Finally, innovation is suggested by new curvilinear shapes and motifs, such as the “Lapita face” (Carson et al. 2013:27-30). Carson and colleagues (2013:20) argue that these similarities do not represent diffusion of pottery technology but, rather, are suggestive a shared system of “cultural meaning or context” that denotes the movement of people familiar with this material culture repertoire. Despite contradictory results detailing the speed and route with which Austronesian speakers enter the Bismarcks and subsequently move east, linguistic, genetic and archaeological evidence demonstrates the arrival of a new group of people coinciding with the appearance of Lapita pottery, fitting well with Green’s (1991:298) Triple-I model.

Regardless of how Lapita originated, once in place, this cultural complex spread with remarkable speed to Remote Oceania, one of the last uninhabited regions of the globe. Questions regarding the impetus for such large-scale voyaging abound, not only those relating to social factors of motivation, but technological seafaring capabilities as well. While these questions are relatively difficult to address due to lack of archaeological evidence, those concerning interaction within and between Lapita regions are arguably more easily answered by the relative abundance of ceramic material.

As the Lapita ceramic design system moves east, diversification in design motifs and structure change across temporal and spatial boundaries (Burley et al. 2002; Summerhayes 2000b). Green (1979:42) was the first to identify differences in design application across the Lapita range, noting distinctions between a “Western” and “Eastern” Lapita style. Subsequent ceramic analyses have further sub-divided these regions into “Far Western” (Anson 1983), “Southern” (Sand 2000, 2001), and “South Papuan” (David et al. 2011; McNiven et al. 2011) “provinces” largely on the basis of design. Recent work challenges such distinctions (Burley and LeBlanc 2015;
Summerhayes 2000b, 2010), opening up new and exciting questions about interaction throughout the Lapita world.

While a focus on ceramics dominates the Lapita literature, several other avenues of research including isotope analysis, zooarchaeology, geochemistry, genetic analysis of human and animal bone, and non-ceramic material culture studies of obsidian/volcanic glass, and shell and adze technology, are providing additional perspectives on Lapita lifeways. Such analyses, along with refinement of Lapita ceramic design analysis and an overall more integrative approach with linguistic and genetic research have much to offer and are beginning to pave the way forward in Lapita research.

2.1. Lapita Archaeology as Viewed through a Ceramic Lens

Throughout Oceania, Lapita is definitively identified by the presence of distinctive low-fired earthenware pottery with ornate curvilinear and rectilinear dentate-stamped designs. Given that Lapita pottery often comprises the bulk of excavated material culture from Lapita sites, this pottery, and more specifically, the design, has been the object of studies focusing on interaction, exchange and settlement patterns. Lapita designs were created by various sized straight, curved or circular comb-like tooth stamps (Siorat 1990). Each stamp produced a design element, combined in highly regularized ways to form designs motifs and fields (Mead 1975a; Sharp 1988). Other decorative techniques include impression, incision, appliqué, modeling and cut-away relief (Green 1979:40). The limited number of rules used to construct motifs and overall similarity in design elements across the Lapita range signals the existence of a unified design system. Nonetheless, regional differences in vessel form, style, and frequency of decoration do occur, leading Green (1979) to propose the existence of Western and Eastern Lapita regions, the former consisting of New Caledonia, Vanuatu and areas further west in Near Oceania, with the latter comprised of Fiji and islands to the east (Summerhayes 2000a).

Aside from the Western and Eastern Lapita Provinces, research has also revealed the presence of other distinct Lapita regions. Anson’s (1983) analysis of Lapita
design at the sites of Ambitle, Talasea and Eloaue in the Bismarcks defines a “Far Western” Lapita “province” by the presence of the most complex vessel forms and intricate decorative motifs in the Lapita repertoire. A multivariate analysis of motif type and frequency leads Anson (1983) to argue that Lapita assemblages cluster primarily by geographic as opposed to temporal variables, with Western and Eastern Lapita provinces having more similarities in common than either has with Far Western ceramics. The Western Lapita province is defined as the region east of the Far Western province, up to and including Vanuatu, and is distinguished from the latter by less elaborate decoration and a decrease in the number of vessel forms (Spriggs 1997).

Earliest levels of Lapita settlement in New Caledonia show ceramic traits characteristic of the Western Lapita tradition. However, ceramic form and style change soon after initial settlement, leading Sand (Sand 2000, 2001; Sand et al. 2011) to propose a new province termed “Southern Lapita”. This is differentiated from the former province classifications by the regular occurrence of composite rims on carinated pots and the development of stylized dentate-stamped anthropomorphic faces on carinated vessels and flat-bottomed bowls (Sand 2000:26). Sand (Sand 2001:69) views this region’s geographic isolation from the Western and Eastern provinces, as known from lack of trade/exchange, as evidence for a separate “interaction sphere”. This sphere led to the development of different ceramic forms, such as paddle-impressed Podtanean ware which emerges as a continuation out of Lapita (Sand 2000).

The fourth province is termed “Eastern Lapita”, originally taken to include West Fiji, Lau (eastern Fiji), Tonga and Samoa (Green 1979) with the later addition of the Polynesian outliers (Niutatoputapu, ‘Uvea, and possibly Futuna and Alofi) (Kirch 1981, 1988a; Sand 1996). Data from this region will provide the focus for this dissertation. As was discussed above (section 1.4), there is considerable debate concerning degree of interaction between potters throughout this region based primarily on the presence/absence and frequency of ceramic elements and motifs. Green (1979) was the first to find support for a distinct Eastern Lapita region, confirming an “overall west-to-east trend indicative of distance decay,” where Eastern Lapita design was “more simplified and generally rectilinear” as opposed to the “rather ornate curvilinear and fairly elaborate rectilinear” designs of Western Lapita. Important research in the thirty years
since this demarcation has revealed contradictory results (Best 1984; Burley and Dickinson 2001; Burley et al. 2002; Burley 2013; Clark and Anderson 2009; Clark and Murray 2006; Cochrane and Lipo 2010; Mead et al. 1975) and set the stage for a re-evaluation of ceramic design within the region.

The fifth and final province category is the newly named “Southern Papuan Lapita Province” (David et al. 2011; Summerhayes and Allen 2007). On the basis of eight excavated Lapita sites along the south Papuan mainland coast and one inland site, David and colleagues (2011) argue for Lapita occupation between 2500-2900 BP. Ceramics are analyzed on the basis of form and decoration, with results suggesting striking similarity with Lapita ceramics, indicated by the presence of carinated vessels, along with dentate-stamped and impressed decorative motifs. Despite similarities with other Lapita regions, David et al. (2011:586) argue for important distinctions including “predominance of impressions of paired or triple curves made by dentate or continuous-edged thin tools, with an absence of dentate-stamped faces, and an absence of flat-bottom vessels.” Variation in this region consequently gives way to “Early Papuan Pottery,” argued to develop in situ from the Lapita ceramic tradition (David et al. 2011:586). This classification provides an important new chapter in Lapita expansion.

Arguments against the use of “province” categorization to reflect coherent interaction spheres in the Lapita period have been put forth by Summerhayes (Summerhayes 2000a,b, 2010). In a multivariate analysis of vessel form, style, and fabric composition of Lapita ceramics from the Arawe Islands of West New Britain, Summerhayes (2000a) identifies two distinct ceramic groups. The first, Paligmete and Adwe squares D, E, and F can be characterized as Far Western Lapita, while the second group, Apalo and Adwe square G, fall into the Western Lapita category. These groups are differentiated based on differences in percentage of dentate-stamping, vessel proportions, types of design motifs, and chemical characterization of fabric. A comparison of Arawe ceramics with those spanning several Lapita provinces, including assemblages from Tonga, Fiji, and Samoa, identify several shared design motifs. A review of the dates associated with sites sharing motifs indicates that design motifs thought to be unique to the Eastern Lapita region are actually present in later Western
Lapita assemblages (Summerhayes 2000a,b), reinforcing the need for comparison of alternative design attributes.

Summerhayes (Summerhayes 2000a:163) argues that shared design motifs are indicative of continued interaction between Near and Remote Oceania, suggesting that both temporal and geographic factors play an important role in Lapita ceramic change. He calls for the Lapita province classification system to be replaced with an Early, Middle, and Late Lapita taxonomy to reflect the temporal nature of ceramic change, as evidenced by a general decrease in both the number of vessel forms and predominance of dentate-stamping over time. Summerhayes’ (Summerhayes 2000a,b, 2010) classification system has not been enthusiastically accepted by Oceanic archaeologists as a review of recent literature still defines ceramic style and form by the province typology (Clark and Anderson 2009; Irwin et al. 2011; Sand et al. 2011), with some researchers (Bedford et al. 2009) opting to use both classification systems interchangeably. Lack of agreement among Oceanic archaeologists regarding Lapita interaction on the basis of ceramic form and style requires supplementation of ceramic analysis with other material cultural studies and a re-evaluation of the analytical design methods that are currently used.

**Purpose and Meaning of Lapita Design**

The loss of dentate-stamping marks the end of Lapita as recognized by archaeologists. Reasons for the loss of this decorative system are speculative at best (Burley et al. 2002), although it has been suggested to result from the loss of traditional ceramic knowledge (Burley and LeBlanc 2015) and/or “a change in the social desire to keep the art going” as people moved further away from the homeland (Chiu 2012:6). If this knowledge was held by a select few, perhaps a master potter or potters (LeBlanc 2011), then loss of these individuals in colonizing canoes or soon after landfall in a new settlement may have impeded transfer of pottery technology to next generation potters (Bell 2015; Burley and LeBlanc 2015). This, combined with increasing distance from the homeland, was likely to have impacted sustainability of the Lapita ceramic repertoire.

Reasons for loss of the decorative system lead to questions surrounding the meaning and use of Lapita design. While speculative, several hypotheses have been put
forth. Kirch (1997) and Chiu (2003, 2005, 2007, 2012) argue that Lapita designs represent “house-based” social groups as signified by “face” motifs, with their placement on ceramic vessels (i.e. within friezes or complex zones) marking social boundaries (Chiu 2007:245, 260). Use of varying face motif alloforms may have signalled house-group membership and position within the social hierarchy (Chiu 2007:260). Lapita “face” designs have also been argued to represent ceremonial sea turtles (Terrell and Schechter 2009). More recently, the designs, specifically those on flat-bottomed ceremonial dishes, have been theorised as having been part of elaborate rituals performed during first settlement (Sand 2013). Such ceremonies have been envisioned to result in the ritual breaking of “decorated pots bearing ‘family-specific’ motifs...being purposefully scattered on the land as a form of ‘alliance’ with the place” (Sand 2013:4). Regardless of what Lapita design represents, the study of its variation across space and time has much to offer hypotheses regarding Lapita interaction.

2.1.1. Ceramic Production and Exchange

Petrographic analysis of ceramic clay and temper indicates that Lapita ceramic production was predominantly local (Chiu 2005; Dickinson and Nunn 2013; Dickinson and Shutler 1979; Dickinson and Shutler Jr. 2000; Dickinson et al. 1996; Kirch 1990; Martinsson-Wallin 2007; Poulsen 1987), although instances of non-local raw material usage have been identified (Burley and Dickinson 2001, 2010; Dickinson and Nunn 2013; Hunt 1989; Kirch 1990; Nunn et al. 2007). Several scholars have noted homogeneity in production techniques (Chiu 2005; Clark and Anderson 2001; Kirch 1997, 2000; Sand et al. 2011) and have put forth several hypotheses to account for this pattern, focusing on patterns of trade, migration, and potter mobility (Chiu 2005, 2007, 2012; Cochrane 2008; Cochrane and Lipo 2010; Dickinson and Shutler 2000; Sand 2007; Summerhayes 2010). Given that the majority of Lapita ceramics were manufactured with local materials, similarity cannot be explained in terms of exchange but as Anson (1983:266) notes, “in terms of closely shared and communicated cultural characteristics,” an argument put forth by others as well (Summerhayes 2000a:12).

The degree to which Lapita ceramic production is representative of specialization has been debated. Specialization here refers to “the regularised production of a specific
good or service above what is required for personal use, by a group of people that is restricted in size” (Hogg 2012:5). As noted in a review of the literature by Hogg (2012:1), Kirch (1988b, 1990, 1997) and Hunt (1988, 1989) advocate a pattern of “specialized regional production” during the Lapita period in which pottery was produced by groups of sedentary specialist potters for trade within a regional exchange network. A second model put forth by Summerhayes (2000a) sees Lapita potters as participating in “mobile specialized production,” whereby specialist potters produce pots with a variety of local and non-local materials for use within their home village (Hogg 2012:1). In neither model is specialization quantified, making it difficult to test for similar patterns in other Lapita ceramic assemblages.

The apparent lack of potter conservatism in terms of raw material acquisition argues against the existence of specialized production centres during the Lapita period and is instead suggestive of household-based production (Bedford 2006; Bedford et al. 2009; Chiu 2003; Summerhayes 2000a). Household production has been argued for Lapita ceramics at the cemetery of Teouma, Vanuatu based on “striking variation in vessel form and design structure” (Bedford et al. 2009:230). However, Bedford and colleagues (2009) do not provide quantitative ceramic attribute data with which to verify a lack of specialization. Chiu (2003) also finds no evidence for ceramic specialization at site 13A in New Caledonia based on a lack of correlation between temper type, decorative techniques, elements, and vessel form, again, suggestive of household production. Overall homogeneity in ceramic production techniques and a lack of homogeneity in raw material use suggests that Lapita potters shared a unified knowledge of production that proved adaptive to all environments encountered throughout the Lapita range.

2.2. Debate Concerning the Eastern Lapita Province

In the easternmost range of Lapita settlement, as elsewhere in the Lapita diaspora, Lapita potters adapted to their environment and continued to use dentate-stamped ceramics. This region is defined in contrast to others by simplification in dentate design and a decrease in density of dentate application. However, this generalization does not hold true when ceramic assemblages within the region are compared. Although
not yet quantified, dentate density varies widely, as does the type and frequency of
design elements and motifs. This variation leads to varying interpretations concerning
interaction and migration patterns within the Eastern Lapita Province.

Interpretation of interaction between West Fiji, East Fiji (Lau), and Tonga in
particular, has sparked considerable debate. The orthodox model of Lapita migration
envisions a rapid and continuous colonization of islands in a west to east progression,
deemed a “wave-of-advance”, with Tonga settled from migrants originating westwards in
Fiji (Sheppard 2011). Support for complex migration patterns is provided by petrographic
and portable X-Ray fluorescence (pXRF) of temper inclusions of exotic-appearing
ceramics excavated from Nukuleka, the earliest Lapita site in Tonga (Burley and
Dickinson 2001, 2010). PXRF analysis suggests that several tan paste sherds found in
the earliest levels of the founder settlement are distinct from the majority of red paste
Lapita ceramics found in Tonga (Burley and Dickinson 2010). Petrographic analysis
further indicates a non-local source locale based on temper composition (Burley and
Dickinson 2001). The exact source location of these sherds is unknown, although it is
hypothesized to be a dacitic high island west of Fiji (Burley and Dickinson 2010). Given
that Nukuleka is currently thought to represent the earliest settlement in Tonga, dated to
2838 ± 8 cal BP (Burley et al. 2012), the presence of potential exotic sherds in the
earliest layers sourced to somewhere west of Fiji (its closest western neighbour) goes
against expectations of a clinal west-east progression of Lapita migrants throughout
Remote Oceania.

Soon after initial landfall in southern Tonga, Lapita peoples move northward
throughout the Tongan archipelago and into Samoa by 2750 BP, represented by the site
of Mulifanua, the only Lapita site yet known in Samoa (Martinsson-Wallin 2007). Aside
from exotic ceramic sherds, lack of similarity between lithic materials, ceramic styles and
temper following first settlement in Fiji and Tonga corroborate the notion of separate
founder events followed by isolated development trajectories (Burley 2013). The above
suggests that the orthodox wave-of-advance model for Lapita migration is too simplistic
(Burley and Dickinson 2010; Sheppard 2011), a hypothesis that can be tested further
through ceramic design analysis.
2.2.1. Conflicting Results from Element/Motif Ceramic Design Analysis

Poulsen (1987) was the first to systematically analyze Lapita ceramics from the Eastern Lapita Province, and Tonga more specifically. Poulsen excavated six sites along the Fanga ‘Uta Lagoon on the island of Tongatapu during 1963-64. His aim was to assess the extent of pottery production and use throughout Tongan prehistory. In order to do this he recorded attributes related to vessel shape, design units, and placement of decorative features. To understand the complexity of decoration and its frequency, Poulsen developed a design motif coding system for the region, one of the first of its kind in Lapita archaeology. This coding system was essentially a list of motifs based on shape (i.e. rectilinear or curvilinear), discreteness, and presence of repetition within the design repertoire. Letter categories were used to demarcate broad design motifs, with secondary numbers indicating a specific modification to the overall theme. Each assemblage was analyzed based on the coding system, with subsequent statistical analysis used to determine the frequency of specific decorative motifs and their percentage within each assemblage. Results indicate a relative uniformity in design and vessel form throughout the regions studied “with the majority of decorative codes found in all horizons of all sites where decorative pottery occurs” (Poulsen 1987:66). Of particular importance, however, was the observation that later sites had about 1/12 of the decorated pottery by weight than early sites. Also, while simple motifs were present throughout all time periods, complex motifs existed only in early sites (Poulsen 1987:118). Based on this simplification of design through time, Poulsen (1987:132) concluded that Tongan ceramics developed largely in situ without outside influence. Although it is difficult to determine the criteria that was used to indicate complexity, Poulsen’s analysis was an important step in Lapita ceramic design studies. Unfortunately, it has remained largely inapplicable outside of Tonga, due to the specificity of the design system.

Noting the lack of structural descriptions of the Lapita design system, the 1970s saw the development of a semiotic system pioneered by Mead (1975a:19) which aimed to “reveal the steps and rules by which patterns were constructed.” Using ceramic assemblages from an archaeological site on Yanuca, Fiji, Mead (1975a) first identified particular design elements and motifs based on geometric shapes for the region. After
this coding system was developed, he identified the rules by which motifs were
organized onto a vessel surface. He sought to develop a “grammar” of Lapita design,
where the application of elements and motifs could be read like a language. As an
example, if two motifs overlapped and then were repeated east to west, Mead’s notation
system would read:

\[ P = M1 + M2/\text{SUP} + \text{ConRep}/\text{EW} \]

where P represents the process rule, M1 and M2 represent particular motifs, SUP
indicates supposition or overlapping, ConRep refers to continuous repetition, and EW
refers to placement in an overall east to west direction. This led to a notation system for
motif rules that could be compared across Lapita assemblages, where emphasis was
placed on the application of design, rather than on the determination of specific elements
and motifs, the cultural relevance of which are “impossible to isolate and confirm” (Mead
1975a:20). He concluded that potters used a zoning system to apply patterns in a
layered approach using a limited number of elements and motifs that were repeated.
Overall, he advocated that his structural approach was more reliable and “less
susceptible to change” than the listing and comparison of element and motif inventories
(Mead 1975b:67).

Mead’s colleagues followed suit, particularly Shaw (1975) who employed the
semiotic system, this time focusing on sherds from the Fijian site of Natunuku. She
noted that ceramics from this site “consistently follow the zones which have been
established for Yanuca,” as well as similarity in the rules applied to design motifs (Shaw
1975:45,50). However, there does exist more variation of zone use and complexity, with
some zones superimposed onto others. Other differences include minor variation on
motifs. Variation on general motif structure gives way to an expansion of the coding
system, with variations referred to as alloforms. Alloforms indicate local development of
the Lapita design system within each region (Shaw 1975:55) and their presence can be
explained “as a function of regional differentiation in a relatively short period of time”
(Mead 1975:57). A subsequent comparison by Mead (1975b) of the rules of motif
application for the Yanuca, Natunuku, and Tongan material, derived from Poulsen’s
(1987) work, indicates that all regions share similar design rules. Where they differ is in
the size, shape, and combination of elements and motifs, likely indicative of temporal variation (Mead 1975b:60-61).

The Mead system was later revised by Sharp (1988). Like Mead, Sharp (1988:81) was concerned over the lack of objectivity and inconsistency in the process of motif identification within the Lapita literature. Sharp (1988) focused on formally identifying process rules related to the combining of elements to form motifs. In order to do this, Sharp modified Mead’s notation system and analyzed ceramic sherds from archaeological sites within Fiji and the Reef/Santa Cruz Islands in the Western Lapita Province. Sharp (1988) determined that it was not the presence/absence of process rules that differed between the regions, but the frequency with which rules are applied to elements to form motifs. In addition, the combination of process rules was more “complex” for the Reef/Santa Cruz collection as compared to the Fijian collection, meaning that the frequency of process rules per sherd was higher.

Although Green (1990) called for a revival of the Mead and Sharp system over 20 years ago, little mention and use of this system has been employed. Mead’s (1975b:57) astute observations of the differences in regards to the process rules of motif application between Fiji and Tonga suggested that, unlike the presence/absence of motifs, the pattern resulting from a comparison of structural organization likely required “regional differentiation and isolation.” A downfall of these notation systems, however, is that, like the identification of elements and motifs, they require subjective criteria and the assumption that elements were purposefully applied in the processes determined by the analyst. Regardless of the issues, the hypotheses put forth by the approach can be tested further through the application of different structural analytical methods.

Rejection of the Mead (1975a) system, led to a predominant reliance on the comparison of element/motif presence/absence and frequency, especially within the Eastern Lapita Province. Archaeological excavation by Best (1984) within eastern Fiji in the 1980s alerted archaeologists to Lapita design variation within Fiji. Excavations took place at five sites on Lakeba in the Lau group of islands in East Fiji. Two coastal rock-shelters, two hill-forts, and a large site outside of a rock-shelter were excavated, along with several test pits. Hundreds of decorated Lapita sherds were analyzed, likely dating
to as early as 2900 BP. Recorded attributes include those related to vessel form, decoration, and surface treatment, with a total number of 269 categories. Like most studies of Lapita ceramics, the motif data played an important role in the conclusions drawn about degree of interaction between potters. Utilizing Jaccard and Robinson coefficients of motif presence/absence and frequency, respectively, Best (1984) determined that Eastern Lapita ceramics showed a distinct break from the west. The degree to which East Fiji and West Fiji interacted was suspect. However, Best (1984:653) determined that East Fiji (Lakeba) appeared to have more in common with ceramics from Tonga and Samoa than with ceramics from West Fiji, suggesting, “…a break from the west is substantial and real.”

Clark and Anderson (Clark and Anderson 2009) provide a different interpretation to the question of interaction within and between West Fiji, East Fiji, and Tonga. Although noting the obvious issues with using motif inventories to assess interaction between Lapita regions, Clark and Anderson (2009), nevertheless, use Best’s (Best 1984, 2002) motif data and Anson’s (1983) motif inventory to review the patternning resulting from comparison of motif frequency and presence/absence. Assuming that assemblages with a higher percentage of dentate stamping indicate the presence of an earlier occupation as compared to those with a low level of dentate, their results suggest that there was “a relatively early dispersal through Fiji to the Lau Islands and Tonga” (Clark and Anderson 2009:420). Unlike Best’s (1984) interpretation which envisions isolation relatively early after initial occupation, if not different migration episodes, Clark and Anderson (2009) propose continued migration to West Fiji, with possible migration to and interaction with East Fiji, if not Tonga. This hypothesis is expanded upon in an additional re-evaluation of Best’s (1984) data (Clark and Murray 2006).

Two of the more recent studies of Lapita ceramic design have been approached through a cultural transmission perspective (see Chapter 3 for a discussion of this theory in relation to archaeology). Clark and Murray (2006) were the first to apply a cultural transmission approach, which they used to test a model of settlement and interaction within Fiji and Tonga during the Lapita period. The unit of analysis is a list of Lapita motifs previously compiled by Best (1984). Under an unbiased transmission model, they predict that motifs that are greater in frequency at initial settlement should persist
through time, while less frequent designs should decrease due to drift. Results support their predictions and suggest that over time, motifs that remain are those that were present in the highest frequency during earlier time periods, with a general decline in overall motif variation. They argue that this pattern is consistent with the predictions derived from an unbiased transmission model. They conclude that Lau was settled from both West Fiji and Tonga. While Clark and Murray’s (2006) approach represents an important first step in using cultural transmission theory to guide hypotheses, predictions, and methodology concerning the comparison of Lapita design, they do not critically evaluate the legitimacy of using the motif approach over structural approaches. In addition, they do not indicate how they differentiate an unbiased transmission pattern from a prestige or conformist biased transmission pattern, biases which all work to decrease variation through time.

The second study using a cultural transmission perspective to analyze Lapita design is that undertaken by Cochrane and Lipo (2010). Using cladistic analysis along with NeighborNet and phenetic distance network analysis, Cochrane and Lipo (2010) aim to determine population structure among potters in Fiji, Tonga, and Samoa. Based on presence/absence of ceramic motifs from various sites in each region, they conclude that there was a decrease over time in the frequency of transmission. Analyses indicate no clear population structure throughout eastern and western Fiji, suggestive of horizontal transmission or blending (Cochrane and Lipo 2010). Similar to Clark and Murray (2006), Cochrane and Lipo (2010) rely on the motif system compiled by Best (1984). They note, however, the potential complications that can result from relying on motifs analyzed almost 30 years prior and the un-tested assumption that motif similarity indicates shared transmission histories.

Aside from ceramic research, the fields of linguistics and genetics bring additional insight into migration and interaction patterns within the Eastern Lapita region. Linguistics in particular, has raised several questions concerning migration and interaction patterns within West Fiji, East Fiji, and Tonga. Initial settlement of this region suggests there was a unified dialect chain, referred to as the Proto Central Pacific subgroup of the Oceanic language family. Soon after initial settlement, Geraghty (1983) suggests that East Fijian languages of Lau and southeastern Vanua Levu, along with
those of Tonga, diversified from West Fiji into what he calls the Proto Tokalau Polynesian language family. His data indicates that there is “a good deal of evidence to suggest that languages ancestral to those of Eastern Fiji…underwent a period of common development with the languages ancestral to the Polynesian languages”, which include those of Tonga and sites further east (Geraghty 1983:348). This suggests that Tonga was potentially settled from areas within eastern Fiji. In a review of the linguistic literature, Pawley and Ross (2006) also give support to the differentiation between Fijian dialects, suggesting that Proto Central Pacific originated in Fiji and subsequently differentiated into western and eastern dialects. Speakers of the eastern dialect “separated, probably moving to Tonga and other islands in western Polynesia, where Proto-Polynesian developed” (Pawley and Ross 1995:57). The western and eastern dialect divisions within Fiji are still identifiable (Pawley and Sayaba 1971).

Genetic evidence also suggests differentiation among western, northern, and eastern regions of Fiji (Shipley et al. 2015). Through testing of both Y and mtDNA segments from modern populations throughout Viti Levu, Vanua Levu, Kadavu, Lau, and Rotuma, Shipley and colleagues (2015) identify sex-biased admixture, typical of genetic lineages found throughout Oceania (Kayser et al. 2006; Delfin et al. 2012). Y chromosome data suggests that paternal lineages are more similar to Melanesian populations, such as those in Papua New Guinea, while maternal lineages, gleaned from the mtDNA data, appear more “Polynesian”, supporting the hypothesis that Lapita migrants were matrilineal in kinship structure (Delfin et al. 2012; Kayser et al. 2006; Shipley et al. 2015). Of particular importance is the debate surrounding degree of interaction between West Fiji, East Fiji, and Tonga. Shipley and colleagues (2015) provide mtDNA data that suggests both the Rotumans and Lau islanders are genetically more similar to Polynesian populations than are other areas of Fiji. Y chromosome data, however, suggests that the Rotumans and Lau islanders are just as similar to the Melanesians in genetic structure as are other populations within Fiji. Polynesian characteristics within maternal Lau populations may signal potter interaction with Tonga during the Lapita period. Ultimately, Shipley et al. (2015:74) conclude that Fiji is not genetically homogeneous.
More fine-grained genetic evidence on the specific subject of migration and interaction within and between Fiji and Tonga has yet to be gathered. Broadly speaking, genetic evidence of Lapita migration to date, clearly indicates that individuals within Fiji and Tonga can trace ancestry back to early migrations, either fast (Friedlaender et al. 2008) or slow (Kayser et al. 2006; Wollstein et al. 2010), through the Bismarck archipelago across the Near/Remote Oceania border; the pathway of Lapita migration. The homeland location of migrating groups into both Fiji and Tonga has not yet been determined, nor has the presence or absence of admixture between groups once settled, as far as I am aware. This field, however, demonstrates significant potential for future hypothesis testing within the Eastern Lapita region and abroad.

The above ceramic, linguistic, and genetic evidence provide competing hypotheses of Lapita interaction within West Fiji, East Fiji, and Tonga. The research has raised several concerns regarding the methodological approaches used to analyze Lapita material culture. In particular, there is a need to critically evaluate the methods used for ceramic design analysis. Different methods, especially use of varying statistical tests, samples sizes, and attributes, lead to varying conclusions. The role of sample size issues in Lapita archaeology is often a subject that is either overlooked or ignored due to data acquisition issues. This issue must be acknowledged in order to determine if conclusions drawn from hypothesis testing are worthy of further consideration. Of particular importance, however, is the challenge of attribute choice. The element and motif inventory system is not only outdated, but suffers from significant limitations as discussed above. In order to move forward, the first step is to look to the cross-cultural literature to understand methods employed in other areas of ceramic design analysis. This step is undertaken below.

2.3. Ceramic Design Analysis in Cross-Cultural Perspective

Ceramic design analysis refers to the methods used to understand variation in ceramic design. This variation is often used to refer to particular pottery “styles”. The term “style” has had a turbulent past in the archaeological literature, to the point of being referred to as a “proverbial black box” (Conkey and Hastorf 1990:1; see also Munson 2011). Definitions of style are rarely explicit or comparable between ceramic analysts.
(Conkey and Hastorf 1990; Hegmon 1992; Rice 1996; Sackett 1977), but consensus appears to rest on the notion of style as the “potential for interpretation residing in those formal characteristics of an artifact that are acquired in the course of manufacture as the consequence of the exercise of cultural choice” (David and Kramer 2001:172). Thus, style can be viewed as “a way of doing something” that “involves a choice among various alternatives” (Hegmon 1992:517-518). The above definitions do not explicitly allude to design due to the fact that this term has become an all-encompassing way to refer to any type of variation that can be used to describe a distinct group of ceramics (Gosselain 2000; Hegmon 2000; Sterner 1989). For purposes of this dissertation, design will refer to decorative attributes applied to the surface of a ceramic vessel.

Ceramic design analysts rely on two major methodological approaches: (1) element/motif analysis and (2) structural analysis. As discussed above, the utility of the two approaches is debated, as is the extent to which both should be followed. Below is a brief historical overview of each.

2.3.1. Element/Motif Approach

Early studies of ceramic design made efforts to record not only element/motifs, but also the organization of designs on a vessel surface (Amsden 1936; Carlson et al. 1961) and the symmetry of design (Shepard 1948, 1956). For example, Carlson’s (Carlson 1961:15-22) dissertation on White Mountain Redware from East Central Arizona included a description of the decorative field location, layout, motifs, color pattern, hatching, framing lines, line and motif width, along with pattern, “the interplay of primary motifs within the field of decoration” (Carlson 1961:22). Despite early efforts at structural ceramic design analysis, the field was slow to advance, largely due to the lack of whole vessels and large sherds necessary for such inquiry (Canouts 1991; Plog 1980). Design elements/motifs became the go-to method of ceramic design analysis, with several recent studies still opting for this approach (Fleisher and Wynne-Jones 2011; Hart and Engelbrecht 2012; Whalen and Minnis 2010).

Recent studies employ the design element/motif approach to address a wide-range of questions about interaction and exchange. Using a cultural transmission
theoretical framework, several researchers (Clark and Murray 2006; Cochrane and Lipo 2010; Kohler et al. 2004; Shennan and Wilkinson 2001) attempt to discern patterns of learning and interaction based on the frequency or presence/absence of individual design elements/motifs. Hart and Engelbrecht (2012) similarly use a cultural transmission framework to determine whether potters in the northern Iroquoian ethnic landscape of New York, southern Ontario and the St. Lawrence Valley maintained distinct “ethnic” boundaries, by examining ceramics motifs. Acknowledging controversy surrounding “ethnicity”, they define the term as “part of individual identity…actualized through social interactions,” which allows for “the maintenance of social boundaries” (Hart and Engelbrecht 2012:323). Results indicate that ceramic design categories do not form discrete clusters but, rather, show evidence of admixture between geographic territories. Assuming that ceramic design signals group ethnicity, Hart and Engelbrecht (2012) conclude that there was movement of people between traditional territories and that ceramic design was exchanged as part of this interaction. Cunningham (2001:19) has also analyzed design motifs in the Woodland region of Southwestern Ontario and finds an overall degree of homogeneity within assemblages, but also evidence of some “creative freedom” in terms of minor motif variation. Although this variation is not quantified, he argues against homogeneity as a reflection of “ethnicity” and views ceramic design as a product of intensive group production.

Although the methods used to determine discrete elements and motifs in any one region cannot be compared to another, they provide comparable data for the culture-historical area in question. Frequencies of each element/motif are often tabulated and then compared between assemblages with the assumption that the greater the frequency of shared elements/motifs, the greater the degree of interaction between groups (Deetz 1965; Hill 1970; Longacre 1970; Wobst 1977) or as a signal of “more intensive production within a cohesive social context” (Cunningham 2001:19). Although this assumption may hold true in various circumstances, ethnoarchaeological research has indicated that degree of interaction is not always able to be determined through an analysis of elements/motifs, as these aspects of design appear to diffuse easily between social boundaries (Arnold 1983; Friedrich 1970; Gosselain 1992, 2000; Graves 1985; Hardin 1983; Miller 1985).
Studies employing element/motif approaches have been scrutinized for their lack of explicit meaning in what actually constitutes an “element” or “motif” (Plog 1980; Jernigan 1986). Even in cases where methodology is transparent, such methods are not transferable cross-culturally, or even comparable throughout an entire culture-historical region. The degree to which an element/motif reflects the decision of the potter(s) notwithstanding, this approach results in lists of design units that must be modified in order to compare results across a wide region (Clark 2010; Hill 1970; Longacre 1970; Watson and LeBlanc 1973).

Aside from the inconsistency with which elements/motifs are defined, another criticism has been the comparison of elements/motifs that “do not have the property of substitutability” (Plog 1980:42), which is defined as the degree to which any two design elements/motifs can be considered equal alternatives for a potter to choose amongst. Plog (1980) presents an example to illustrate his point. Say that a potter has a design repertoire of three elements: two lines of different width and a triangle. The two lines are not “alternative states of the attribute of form; they are both lines and thus have the same form” (Plog 1980:43). Therefore the act of choosing between the two lines or between one of the lines and the triangle are not comparably equal decisions. Obviously, this can be difficult to argue, given that we do not know the thought process behind the decisions of prehistoric potters. Suffice it to say, the designation of elements/motifs can be a subjective process, with a report on the replicability of suggested designs rarely included with results.

2.3.2. Structural Approaches

Shepard (1956) was one of the first ceramists to outline a comprehensive structural approach to design analysis (for a review of Shepard’s work refer to Canouts 1991). In an effort to make the process of ceramic design analysis more objective, Shepard (1956) recognized that “formal” aspects of design needed to be part of the analytical corpus. By “formal”, Shepard (1956:260) was referring to the structural application of elements/motifs and “characteristics such as symmetry, relation of figure and ground, and balance of dark and light,” essentially, the plan and execution of the design (Shepard 1956:266). Shepard was among the first to advocate for the use of
symmetry analysis in ceramic design, an approach that, years later, would be taken up enthusiastically by Washburn and Crowe (1988, 2004). Shepard’s (1948, 1956) definition of symmetry requires the analyst to determine the fundamental unit of design and the motion by which it is repeated. Despite her efforts, Shepard’s structural approach was not immediately pursued by archaeologists (Canouts 1991).

Several years after Shepard’s (1956) attempt to introduce structural approaches to ceramic design came Friedrich’s (Hardin) 1970 seminal article, *Design Structure and Social Interaction: Archaeological Implications of an Ethnographic Analysis*. Often cited as one of the most fundamental studies of ceramic design structure (Arnold 1983; Carr and Nietzel 1995; Graves 1985; Hegmon 1995, 2000; Plog 1980; Van Keuren 1999), Friedrich’s (1970) 14-month ethnographic study of painting patterns among Tarascan potters in Michoacán, Mexico alerted archaeologists to aspects of decorative style that signal intense communication between potters. She found that, contrary to popular belief, it was not decorative elements or motifs that indicate potter interaction and communication, but, rather, structural aspects of decoration. The most important of these structural features include those that resist diffusion and therefore signal intense interaction: “1) organization of spatial divisions, 2) classification of design configurations, and 3) function of design elements in the configurations in which they occur” (Friedrich 1970:338). Hardin (Friedrich) (1983, 1984; Hardin and Mills 2000) continues to advocate for structural approaches to ceramic design.

Hardin’s research has inspired several studies including Plog’s (1980) analysis of ceramics from the Chevelon area of the American Southwest. Plog (1980:49) uses a hierarchical method for delimiting “primary” and “secondary” design elements, the latter being those that “never occurred by themselves on vessels; they were painted only in conjunction with other forms,” whereas primary elements could occur by themselves or in combination with other elements. In addition to determining which elements were primary or secondary, their location relative to each other, and the manner in which they were combined, Plog (1980) recorded the form of design as either rectilinear or curvilinear, along with the composition of form for primary elements. Composition refers to the in-fill of elements, being either solid, hatched, checkerboard, or a combination of the above (Plog 1980:50). In-fill is also categorized by measurement of line width and
Spacing. Through application of this analysis to 1000 sherds from four different sites, Plog suggests that designs vary with vessel form, with different patterns representing different kinds of style. An increase in design variability over time is taken as evidence for design as functionally symbolic, but Plog (1980) ultimately concludes that design variation cannot be explained by a single factor.

Structural analysis in ceramic design appears to reach its height in the 1980s, a period of intense debate surrounding the use and meaning of ceramic design in social context (Plog 1980; Hole 1984; Jernigan 1986; Washburn 1983a,b; Washburn and Crowe 1988). Washburn’s 1983 edited volume entitled, *Structure and Cognition in Art*, brought together researchers from various disciplines concerned with the structure of art and its context within the social realm. Several authors (Arnold 1983; Hardin 1983; Lathrap 1983) focused on structural approaches to ceramic design analysis.

Within the volume, Arnold (1983) presents an ethnoarchaeological study relating ceramic design structure to the structure of village spatial organization in Quinua, Peru. Arnold (1983) analyzes ceramic vessels through a hierarchical approach beginning with the placement of design zones, followed by the motifs used within specific zones and resultant symmetry patterns, based on Shepard’s (1948, 1956) criteria. Results suggest that the spatial organization of ceramic design fields into vertical zones and further subdivision into horizontal space mimics the division of community space throughout Quinua. The fixation of design zones is analogous to the fixed structure of ecological zones (Arnold 1983).

Hardin (1983) views design structure as the “cognitive system underlying a particular style” and draws heavily upon Shepard’s (1956) outlined approach to analyze Tarascan greenware ceramic painted designs from San Jose, Mexico, collected during ethnographic analysis. Hardin (1983) interviewed potters to gain a sense of how they view the organization of the design field and which units of design they use to distinguish the work of different potters. She discovered that it is the design configuration, the arrangement of one or more kinds of design elements used to fill a design zone, which is the basic unit of design for potters. She argues overall that a shared cognitive structure between potters is needed to ensure stylistic homogeneity.
Lathrap (1983) presents an ethnographic account of a particular Conibo artist who developed her own distinctive ceramic design style, emulated by fellow potters wherever she travelled to. Her prestige resulted in “pockets of stylistic uniformity” throughout a wide range of locations (Lathrap 1983:30). In addition, Lathrap (1983:36) found no evidence to indicate that matrilocal residence leads to stylistic homogeneity in the extended family unit (the conclusion reached by ceramic sociologists), suggesting that it is long-term processes that must be sought in order to explain stylistic variation and not “casual factors” of post-marital residence. Although Lathrap (1983) does not analyze ceramic design by any formal criteria, his ethnographic account has much to add to the archaeological understanding of the social processes behind variation in ceramic design.

The final contribution to the volume that addresses ceramic design is Washburn’s (1983) exploration of the use of symmetry analysis. Through two case studies of Neolithic ceramics in Greece and the Aegean, she tests the assumption that symmetry as a structural attribute reflects temporal and spatial cultural boundaries. She analyzes the symmetry of sherds from seven levels at Knossos, representing a 3000-year period, and finds that changes in symmetry correlate with major transitions in interaction patterns. From this and other studies of symmetry in ceramics and other media (Washburn 1977), she concludes that symmetry, as an attribute of design structure, signifies cultural group boundaries, unlike design elements which may be used by a variety of cultural groups who interact to a very limited degree, if at all (Washburn 1983). Washburn’s use of symmetry stimulated a revival in this field, long after Shepard’s call for its use. In 1988 Washburn and Crow published, Symmetries of Culture: Theory and Practice of Plane Pattern Analysis, a handbook of standard procedures to follow when analyzing symmetry. This was followed by an edited volume in 2004 where the approach was applied to several media in both ethnographic and archaeological context. They define symmetry as it is used in geometry to mean a “rigid motion” (Crowe 2004:3) that creates a pattern (Washburn and Crowe 1988). They outline plane pattern symmetries, which refer to patterns whose symmetry occupies portions of the plane or a surface that can be considered planar when made flat (i.e. a
ceramic vessel). They describe finite patterns (those that are not repeated) as well as one-dimensional and two-dimensional repeated patterns. They adopt a four-symbol notation system, originally developed by Russian crystallographers, which allows for standardization and simple comparison of results across studies. By following the flow-charts provided in the handbook, the researcher can easily determine the four-symbol code that best describes a given symmetrical pattern, offering a relatively objective way in which to analyze designs that can easily be repeated and applied cross-culturally.

The hierarchical structural approaches outlined above came under scrutiny by Jernigan (1986). He argued that the “element-motif-layout framework” was essentially ambiguous as a comparative analytical approach. Jernigan replayed the old debate that definitions for terms such as “element”, “motif”, “layout”, and “filler” were not made explicit in the literature and were therefore unable to be replicated. He found further fault with the hierarchical approach for never having been used to describe a ceramic decorative style in its entirety, noting that scholars rarely provided a comprehensive list of all element/motifs and structural aspects of a decorative style. He critiques Plog’s (1980) work in general for blindly accepting Friedrich’s (1970) structural attributes without any evidence for a relational analogue between the social milieu in which Tarascan potters worked in the 1960s and that of the Anasazi in AD 1000. As an alternative, Jernigan (1986) proposes that “schemata” become the attribute of analysis. By “schemata” he is referring to “a configuration or pattern of configurations for which we have evidence that the configuration or pattern was conceived as a distinct unit by the makers of the style” (Jernigan 1986:9). Despite the fact that he defines schema three times, it is not clear how the analyst is to go about discerning what the potter would have chosen as the basic design unit. It if for this reason that Jernigan’s approach has not been replicated and he has been criticized for advocating a methodology just as ambiguous as those he was trying to avoid (Hegmon 1995; Plog 1995).

Structural approaches to ceramic design continued into the 1990s, particularly those advanced by Hegmon (1994, 1995) and Van Keuren (1999). Hegmon (1995) takes a combination of the element/motif and structural approach and applies it to an analysis of ceramic design in the American Southwest during the Early Puebloan period. She defines design structure as “the organization of designs, including layout, symmetry, and
the use of elements in particular contexts or combinations” (Hegmon 1995:157). The structural approach, for her, is a way of describing attributes in terms of the rules used to execute the design, which can then be compared in varying contexts. Building on the structural work of Hardin, Van Keuren (1999) analyzes ceramic design from 83 whole painted Cibola White Ware vessels dating to the Pueblo III period (AD 1275-1325) throughout eastern Arizona. Van Keuren (1999:27) notes that ceramic ethnoarchaeological studies have alerted archaeologists to the fact that design elements often do not signal social behaviours associated with ceramic production (i.e. Arnold 1984; Friedrich 1970; Gosselain 1992; Graves 1985; Hardin 1983; Miller 1985). Given this, he chooses to use a structural analytic approach, focusing on the sequence of design execution at the brushstroke level, arguing that “variability in the painting sequence records information about potter life-history” and learning patterns (Van Keuren 1999:27).

2.3.3. Current Approaches to Ceramic Design Analysis

Although progress was made towards structural analysis during the 1990s and early 2000s (Bowser 2000; Crown 1999; Forge 1990; Gray and Albaugh 1992; Hardin and Mills 2000; Hilgeman 1991; Siorat 1990), it seems to not have elicited enthusiasm among ceramicists, as examples of structural approaches to ceramic design analysis are rarely found in recent literature. Indeed, archaeological ceramic analysis in general appears to have waned. Despite the decline, a few relatively recent studies have appeared which largely combine aspects of both the element/motif and structural approach (Brody 2004; Carson et al. 2013; Hegmon and Kulow 2005; Nelson et al. 2011; Peregrine 2007; Washburn et al. 2013).

Hegmon and Kulow (2005) apply a structural approach to analyzing chronological change in ceramic design on vessels from Southwest New Mexico dating to between AD 750-1150. They develop a methodology for determining instances of design innovation: “processes that include both invention and adoption, the introduction of a novel form and its acceptance” (Hegmon and Kulow 2005:314). The methodology consists of determining “microstyles” (presence and kind of representational signs, symmetry, and associated motifs), design layout, and representational design (largely
based on the coding system by Brody (2004)). They first devised a system for identifying anomalies, “an unusual design, which deviates from the norm...” (Hegmon and Kulow 2005:321). This consists of classifying structural design rules (Hegmon 1995), followed by the identification of unusual designs that do not adhere to the structural rules. After the anomalies are identified, their increased use through time can be taken as evidence that they became innovations, as opposed to “isolated anomalies,” which do not become incorporated into the design repertoire (Hegmon and Kulow 2005:321). Hegmon and Kulow (2005) conclude that their approach allows for comparisons between innovative designs with those found on ceramics from other regions, ultimately illuminating possible patterns of interregional interaction or periods of social change.

Of the few recent studies that do mention ceramic design analysis, the methods employed are not always entirely explicit (Carson et al. 2013; Gijanto 2011; Haour 2011; Nelson et al. 2011; Washburn et al. 2013). Focusing on the American Southwest, Nelson and colleagues (2011) examine the relationship between ceramic design diversity and population size, posing the question: as population density increases, does social conformity increase, resulting in design homogeneity? They base ceramic design diversity on richness measures, which is determined by the number of painted wares present. They conclude that as population density increases, ceramic design diversity decreases, indicative of social conformity. Also working in the American Southwest, Washburn and colleagues (2013) have continued with symmetry analysis following the work of Washburn and Crowe (1988), using change in symmetry patterns as evidence for migration. Finally, in a study of Lapita pottery from the South Pacific, Carson et al. (2013) use the attributes of red slip, vessel form, decorative techniques and tools, placement of decoration, and motifs to elucidate the origins of the Lapita ceramic style. Although specific aspects of their technique remain elusive (i.e. what criteria was used to designate motifs?), the study makes the important step of incorporating structural analysis into Lapita ceramic design. These recent studies highlight the importance of ceramic design for determining periods of interaction and the marking of social boundaries, issues that are still debated and can be addressed through the use of both the element/motif and structural approach to ceramic design.
2.3.4. Conclusions Drawn from Ceramic Design Analysis

Several lessons have been learned from archaeological ceramic design analysis. The first is that style and function are not mutually exclusive. Decorative design has been shown to actively signal information and thus has a function in certain social contexts (Nelson et al. 2011; Pirkirayi 2007; Stark 2003). Ethnoarchaeological studies have identified a variety of ways in which ceramic decoration signals meaning and what that meaning is in different contexts (Bowser 2000; Bowser and Patton 2008; David et al. 1988; Hegmon 1992, 2000; Herbich 1987). Design can be used to signal in-group affiliation (Sterner 1989; Weissner 1977), social boundaries (Hays 1992; Wobst 1977), or lack thereof (Hegmon 1994, 1995), political affiliation (Bowser 2000; Bowser and Patton 2008), economic and social power (Cunningham 2009; Gijanto 2011; Whalen and Minnis 2010), and can be used by individuals within the private context to communicate with the spirit world (Sterner 1989). Design has been argued as an active form of communication situated within activities or performance characteristics (Schiffer and Skibo 1997; Schiffer 1999). Ceramic vessels as a medium have also been shown to act as a barrier to communication through design, given its constraints of visual perception and size to out-group members (Brody 2004; Eerkens and Lipo 2005; Hardin 1984; Weissner 1977). While these studies are important for alerting archaeologists to the possible range and meaning of material cultural variability, they nevertheless stress the difficulty with which the function of ceramic design can be understood without the context of ethnographic observation and more detailed studies on human cognition (Hardin 1983; Munson 2011; Rice 1996; Washburn 1983a).

A second lesson is the notion that mechanisms of cultural transmission are integral to the understanding of ceramic design variation. Patterns of cultural transmission have become important aspects of ceramic design research and material culture studies in general (Stark et al. 2008a). Several ethnoarchaeological studies have focused on patterns of learning in relation to ceramic design (Bowser 2000; DeBoer 1984; Herbich 1987; Miller 1985; Sterner 1989) and form (Kamp 2001; Degoy 2008; Gosselain 2008; Wallaert 2008). Results from these studies suggest that learning patterns at the individual level are complex; several different patterns of transmission can lead to homogeneity and heterogeneity of design and form, depending on context.
Ceramic design homogeneity has been linked to the process of conformity, a form of bias that can occur during the process of cultural transmission (Nelson et al. 2011; Gosselain 2000; Herbich 1987; Kohler et al. 2004; LeBlanc 2012). Homogeneity in ceramic design can also be the result of intense interaction between potter compounds, resulting in transmission and maintenance of pottery styles between peers (DeBoer 1984).

Ceramic design analysis has also revealed that reasons for and rates of change in ceramic design are complex. Archaeological explanations of ceramic change often center on interaction between new groups of people (Capone and Preucel 2002; Mills 2002). During times of tension and revolt, potters can manipulate their designs to signal resistance (Mills 2002) and maintain group cohesion (Capone and Preucel 2002). Other explanations associate design change with changing social beliefs and their symbolic expression (Braun 1991), change in trade networks (Washburn 1983) and economic context (Stark 1991; Wallaert-Pêtre 2001), population loss or gain (Graves 1985; Neiman 1995), and loss of visual models (Hardin and Mills 2000; Hegmon 2000). Such interpretations view change as a slow process, often on the order of centuries (Braun 1991). Ethnoarchaeological research, on the other hand, has demonstrated that rates of ceramic design change can be fast (DeBoer 1990), even on the scale of decades (Hardin and Mills 2000; Stark 1991).

In their “ceramic ethnohistorical archaeology” (Hegmon 2000:134) study, Hardin and Mills (2000) analyze a historic collection of Zuni ceramics before and after intense periods of ethnographic collection in the late 19th century. They first separate vessels based on use-life, which they interpret from use-wear patterns based on the amount of abrasion through slip at the vessel base. They identify three different vessel use-life categories. The smallest bowls have the least amount of wear and therefore the shortest use-life, suggesting that they are the best candidates for examining patterns of design change through time. They recorded the attribute of symmetry (based on Washburn and Crowe 1988) to represent design style. Results indicate that vessels with the shortest use-life change more rapidly, in relation to symmetry pattern. They conclude that loss of visual models is the most likely explanation for design change which resulted from the loss of ceramics during ethnographic collection in the 19th century and the occurrence of
a smallpox epidemic during the same time period (Hardin and Mills 2000). This along with stylistic drift, increasing commercialization, and population change led to stylistic change in a matter of years (Hardin and Mills 2000). It is clear that there is much more to learn about ceramic design change, with the context of such change being crucial to comprehensive explanations.

Finally, analysis of ceramic design has shown that element/motif and structural approaches should be used in unison when possible. Since the early days of ceramic design analysis in the American Southwest, archaeologists have advocated the combined approach (Amsden 1936; Carlson 1961; Colton and Hargrave 1937; Shepard 1956). Although the element/motif approach is sometimes the only appropriate method for an assemblage consisting of small sherds, the methodology of defining elements/motifs should be more transparent and combined with structural approaches where appropriate. Given that ethnoarchaeological studies indicate structural aspects of design to be indicators of social interaction and cultural transmission (Arnold 1984; Bowser 2000; Friedrich 1970; Herbich 1987), it is time for a revival of such approaches in the ceramic design literature so that debates related to the function and meaning of style cross-culturally can continue to be addressed.

2.3.5. Lessons for Lapita Ceramic Design Analysis

The above review of the cross-cultural literature on ceramic design analysis has much to offer the field of Lapita ceramic studies. Although Lapita archaeologists have typically relied most heavily on element/motif analysis, as the above review illustrates, structural approaches represent a potential way forward. Not only do structural approaches provide additional methodological avenues, but also provide theoretical frameworks for hypothesis testing and interpretation of the application of ceramic design.

Although rarely questioned in Lapita archaeology, the information signalled by element/motifs may differ to that signalled by the structural application of design. This suggests, if not requires, that both approaches be used to test hypotheses of interaction and migration. This is especially true given that ethnoarchaeological research has indicated that motif categories of design may diffuse more easily within and between
potter collectives than structural attributes of design. This is based on the theoretical premise that apprentice-style transmission is required to master structural attributes, whereas simple copying mechanisms of transmission can be utilized to apply elements and motifs. Cultural transmission theory seems to best reflect these theoretical assumptions; a framework which has begun to influence hypothesis testing using Lapita elements/motifs (Clark and Murray 2006; Cochrane and Lipo 2010).

Aside from theoretical lessons, studies of ceramic design have provided methodological avenues that could be used to study Lapita ceramics. Methods relating to the analysis of structural application of design deserve particular note. As was noted early on in the field by Shepard (1956), attributes related to the plan and execution of design elements/motifs need to be part of the analytical corpus. More specifically, later studies have indicated which attributes appear to be most objective and fruitful in comparison of assemblages. These include, identification of design zones and hierarchical placement of zones, rules related to the placement of element and motifs within specific zones, symmetry patterning, identification of innovated element/motifs, and direction of tool application (Washburn and Crowe 2008; Hegmon and Kulow 2005; Van Keuren 1999). While several of these are applicable to Lapita ceramics, several still fall short in terms of providing explicit methodological details and often require large ceramic vessels for analysis. Drawing from the methodological approaches outlined here, I develop a unique structural approach to Lapita ceramic design analysis which relies upon the theoretical tenants mentioned above.

2.4. Chapter Summary

This chapter has set the stage for the development of a new structural approach to analyzing Lapita ceramics. A brief review of Lapita archaeology, with particular emphasis on ceramic design analysis was first outlined. This was followed by a discussion of issues of methodological concern with hypothesis testing within the Eastern Lapita Province, the regional focus of this dissertation. Acknowledging such inconsistencies, a review of the cross-cultural literature on ceramic design analysis was given to provide a wider context of the field and potential inspiration for the analysis of Lapita ceramics. Finally, a brief discussion of the applicability of cross-cultural theoretical
and methodological approaches to Lapita ceramics was presented. This theoretical focus will be outlined in Chapter 3.
Chapter 3.

Theoretical Framework for Developing a Structural Approach: Cultural Transmission Theory

The ways in which potters learn to create design and apply it to ceramic vessels is of the utmost importance for understanding patterns of interaction. This appears to be the critical factor creating disparity between advocates of the element/motif and structural approach. Design is a complex phenomenon requiring the analyst to consider the factors of cognitive psychology, biology, and social group interaction as all contributing to the “complexity of the artisan as a human being” (Carr and Nietzel 1995:17). In this regard, a cultural transmission perspective provides a useful theoretical framework from which to understand patterns of design diversity and homogeneity throughout space and time.

Cultural transmission (CT) theory refers to the transfer of cultural traits between individuals. CT theory views human culture as an inheritance system, aiming to identify the processes through which cultural traits are passed between individuals and to explain resulting population-level patterns (Richerson and Boyd 2005; Shennan 2002). In this context, culture is defined as knowledge, values, and other traits influencing behaviour that is learned through mechanisms such as imitation and teaching (Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981). CT theory is also referred to as Dual Inheritance theory, which views culture and genetics as structurally distinct, but equally important inheritance mechanisms through which human evolution takes place (Boyd and Richerson 1985:3-4). Predictions derived from this theoretical framework can be used to determine mechanisms of interaction both within and between groups, questions that are of particular importance to Lapita archaeology. While CT studies of Lapita design have been undertaken in Oceania (Clark and Murray 2006; Cochrane and
Lipo 2010), they have relied upon the element/motif approach of ceramic design analysis, to the exclusion of structural methods, as I have outlined in Chapter 2.

Contributions to and use of CT theory spans several disciplinary boundaries including evolutionary psychology, anthropology, history, linguistics, and archaeology. While contributions from several of these fields will be touched upon, the majority of the focus will be on archaeological applications. The field of archaeology holds much promise for applying testable models of CT as a means of understanding human behaviour in the past (Eerkens and Lipo 2007). Archaeology is the only field with access to the record of human behaviour on the time scale of several, if not hundreds, of generations. In this respect, it has the advantage not only to use CT theory to test predictions of past human behaviour, but also to inform CT theory on a time scale not possible in any other discipline (Eerkens and Lipo 2007).

Although archaeological studies have been slow to adopt formal CT theory, the notion that artifacts are the result of CT has been accepted since the first half of the 20th century when artifact-based chronometric analyses (i.e. seriation and percentage stratigraphy) were developed (Lyman 2008). Early understanding of CT from an archaeological perspective suggested that it occurred through processes of “stimulus diffusion, trade, migration, education (language-assisted), mimicking or imitation (not language-assisted) and learning (self-experimentation)” (Lyman 2008:11). By the mid 20th century, however, it was realized that terms such as “diffusion” were limiting as they provided explanation of results, but not explanation of process. To address this, several anthropologists (Hagerstrand 1968; Heine-Geldern 1968; Linton 1936) suggested that models who were prestigious or influential within a social-network likely affected the transmission process. Spaulding (1954) was the first archaeologist to make explicit the fact that CT operates by person-to-person contact. Expanding this view to artifacts, Philips and Willey (1953) defined “horizons” and “traditions”. The former referring to a type or set of artifacts across a large spatial region over a small temporal period, assumed to be the result of diffusion. A tradition occurred over a long time span but was distributed over a much smaller spatial range and was assumed to represent the evolution of a single cultural group. Binford (1965) treated cultural artifacts as the products of cultural norms passed down through CT, an idea taken up by his student
Longacre (1970) and others (Deetz 1965; Hill 1970) in the realm of ceramic analysis, eventually known as “ceramic sociology”. The above studies, while a step in the right direction, were never able to convincingly test the notion of CT implicit in their conclusions (Lyman 2008).

Modern applications of CT theory in archaeology aim to identify the social processes of CT surrounding the production of artifacts and are largely based on the initial mathematical models of Cavalli-Sforza and Feldman (1981) and Richerson and Boyd (1985). Given that archaeological assemblages often are the result of macroscale processes (i.e. the product of groups as opposed to individuals), difficulty lies in the ability to identify the microscale (individual-level) processes that produced them (Shennan 2011). In order to infer individual-level processes, archaeologists rely upon models of CT derived from ethnographic (Aunger 2000; Hewlett et al. 2011) and ethnoarchaeological research (i.e. Chernela 2008; Herbich and Dietler 2008), as well as research in experimental cognitive psychology (Mesoudi and Whiten 2004; Mesoudi et al. 2006; Mesoudi 2008). Such studies have alerted archaeologists to the complexity of information transfer at the individual level, as it has been shown that several processes lead to equifinal patterns at the group level. Applications of these models to group-level archaeological studies suggest that transmission histories of material culture vary depending on the scale of analysis and the economic, sociocultural, and environmental context of use. Ultimately, CT theory provides testable models of the ways in which group-level phenomena arise through individual-level interaction, a question that lies at the heart of archaeological inquiry.

This chapter aims first to provide an overview of the tenets of CT theory in the context of Dual Inheritance theory. Applications of the theoretical principals of CT will then be outlined, with a major focus on archaeological case studies. Approaches of applied CT theory will be sub-divided on the basis of individual and population-level perspectives, with a discussion of how the former can be studied to understand the underlying processes that contribute to the latter. Finally, the relevance of CT theory to the development of a structural approach to Lapita ceramic design analysis will be discussed, along with CT-derived hypotheses and predictions for each of the three case studies in this dissertation.
3.1. Cultural Transmission in the Context of Dual Inheritance Theory

Dual Inheritance theory posits that human behaviour results not only from genetic selection but also from cultural selection acting on culturally transcribed information and resulting material culture (Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981; Richerson and Boyd 1978). In this view, cultural and genetic transmission mechanisms are analogous in certain respects, but differ in several ways. Both represent inheritance systems on which selection can act. In order for selection to occur there must be variation, the variation must be heritable, and variants must have differential success of reproduction, which, in cultural systems, is measured by successful information transmission as opposed to fitness (Barton 2008). Boyd and Richerson (1985:7) outline several structural differences between cultural and genetic inheritance. For example, in genetic evolution the mechanism of inheritance is the gene, whereas in cultural evolution the mechanism is social learning. Other differences include generation length, which is more variable in cultural systems, and the degree to which individuals are developed when acquiring information, which, in cultural transmission, occurs after initial stages of development. Finally, cultural traits are acquired through the copying of phenotypes as opposed to the inheritance of genotypes. Despite these differences, several aspects of the two systems of inheritance are sufficiently alike to be analyzed through a Darwinian perspective, predominately the fact that both result in the replication of variants (Richerson and Boyd 2005; Shennan 2009). It is this aspect of information replication that CT theory is concerned with.

Ideas of culture as a system of inheritance amenable to the force of selection were first proposed in the 1960s and 1970s in the fields of psychology (Campbell 1965, 1972, 1975), anthropology (Cloak 1975, 1976), and evolutionary biology (Durham 1976). However, it was the population geneticists Cavalli-Sforza and Feldman (1973, 1981) who “developed the most sophisticated mathematical treatment of cultural evolution” during this period (Richerson and Boyd 1978:131). Cavalli-Sforza and Feldman (1981) viewed CT processes as analogous to those in the study of epidemiology. Developing mathematical models and terms derived from this field, they sought to understand the nature of CT processes and to predict conditions in which such processes would evolve.
Cavalli-Sforza and Feldman (1981:62) acknowledged two critical stages of CT: (1) awareness of a cultural trait and (2) acceptance of the trait, during which cultural selection can occur. Selection in this context refers to any biased mechanism that affects the chances of a trait being successfully transmitted. Cultural traits or variants refer to information stored in the mind that is passed between individuals during transmission (Richerson and Boyd 2005:63).

Cavalli-Sforza and Feldman's (1981) mathematical modeling of CT was concerned with transmission at the individual level. Boyd and Richerson (1985, see also Richerson and Boyd 1978), in contrast, developed models of CT at the level of the group. Here, they sought to understand how forces of human CT interact with environmental circumstance to guide cultural evolution. Acknowledging culture as a population-level phenomenon, Boyd and Richerson (1985) modeled CT with the cultural population as the unit of analysis. This scale of examination spoke directly to archaeological theory and practice which views cultural artifacts as the physical manifestation of information and is largely concerned with group-level processes of interaction (O'Brien et al. 2010). Archaeological studies (Bettinger and Eerkens 1999; Cochrane and Lipo 2010; Collard and Shennan 2000; Kohler et al. 2004; Lipo et al. 2006; Lyman and O'Brien 2000; Neiman 1995; O'Brien 2008; Shennan and Wilkinson 2001; Stark et al. 2008b; Steele et al. 2010, among others) have begun to model prehistoric CT processes in order to explain material cultural variation across temporal and spatial boundaries.

Of importance to both the individual and group-level perspectives of CT is the unit of inheritance. Details surrounding physical properties of this “information” are hotly debated (Aunger 2010, 2003; O'Brien et al. 2010; Pocklington 2006). Dawkins (1976) coined the term “meme” to represent discrete cultural variants capable of reproducing themselves, as directly analogous to units of genetic inheritance (genes). The existence of memes has yet to be proven, with consensus resting on the fact that knowledge of such units is unnecessary to understand mechanisms of cultural change and stability over time (Aunger 2003, 2010; Atran 2001; Richerson and Boyd 2005; Shennan 2002).
Regardless of the existence of memes, CT results in cultural “phenotypes” (Boyd and Richerson 1985:33), physically manifested through material culture. It is the study of variation in cultural phenotypes that CT theory is concerned with. CT is studied by way of content, context, and mode of information transfer (Eerkens and Lipo 2007). Content refers to the actual information that is being passed within or between generations. Context refers to the physical and social setting in which the transmission of information occurs, while mode refers to the mechanisms through which individuals share and acquire information. The latter has been the most widely studied through a CT perspective.

The mode of CT is concerned with the direction of information transmission and the processes acting on resulting cultural information. Terms for direction (vertical and horizontal) were borrowed from the field of epidemiology by Cavalli-Sforza and Feldman (1981). Vertical transmission refers to information transfer between parents and offspring, while horizontal transmission denotes transfer between individuals of the same generation, regardless of degree of relatedness (Cavalli-Sforza and Feldman 1981:54). Cavalli-Sforza and Feldman (1981:54) also introduced the term “oblique” to refer to transmission between generations by an elder other than a parent. Other scenarios include one-to-many and many-to-one transmission (Cavalli-Sforza et al. 1982).

Several forces act on cultural traits at both the individual and group levels, which can be divided into biased and unbiased processes. Unbiased refer to those acting solely on underlying trait frequency, with each variant having the same probability of being copied (Bentley and Shennan 2003; Boyd and Richerson 1985). This process has been demonstrated as analogous to biological models of neutral evolution, where the effective population size and innovation rate are the only factors influencing trait frequency (drift) (Crow and Kimura 1970; Ewens 1972). Archaeological applications of the neutral model of unbiased transmission were first undertaken by Neiman (1995) and have subsequently focused on “selectively neutral” traits (Dunnell 1978; Lyman and O’Brien 2000), which are assumed to represent those that are not driven by selective forces, but vary randomly in an assemblage (Dunnell 1978:199).
Biased transmission occurs when any force acts in favour of a particular trait (or traits) (Boyd and Richerson 1985; Richerson and Boyd 2005). Boyd and Richerson (1985:10) originally conceived of three types of biased transmission: “direct bias”, “frequency-dependent bias”, and “indirect bias”. “Direct bias” refers to situations in which individuals choose between alternative cultural variants based on the content of the trait and how effective the outcome of choosing that trait appears to be. “Frequency dependent bias” is, as the name suggests, a process in which individuals choose variants based on how rare or common they are in the population. When the most common traits are selected, the force is referred to as “conformist bias” (Richerson and Boyd 2005:120). “Indirect bias” occurs when the learning process is affected by the context of the situation (i.e. wealth of models) rather than by the content of what is actually being transmitted. For example, individuals may copy “prestigious, powerful, or wealthy” models, referred to as “prestige-biased” transmission (Richerson and Boyd 2005:124), without evaluating the effectiveness of the cultural trait they are copying. “Guided variation” can also occur and is defined as situations in which individuals choose between existing variants within a population, subsequently altering the traits through trial-and-error learning and passing the resulting variants on to the next generation (Bettinger et al. 2003; Boyd and Richerson 1985; Richerson and Boyd 2005).

Shennan (2011) has categorized the aforementioned biases to reflect the major process that affects what is transmitted. The newly named categories are “results bias”, “content bias”, and “context bias”. “Results bias” refers to instances in which individuals change the way they do something based on how effective the observed actions of others appear to be. In other words, individuals choose variants based on the ‘results’ of other’s choices. “Content biases” are those affected by the intrinsic properties of transmitted information that makes it “more or less memorable for reasons relating to the structure of the mind or the strong reactions… [it] invokes” (Shennan 2011:1071). In this case, it is the content of what is transmitted that is the most influential factor affecting transmission. Finally, “context biases” are defined as “aspects of the context of learning that affect what is transmitted” (Shennan 2011:1071). This category includes “conformist” and “prestige-biased” transmission, as these are processes that depend on the reputation of individuals rather than on cultural variants themselves. The above
categories of bias illuminate the complexity in mode of transmission for cultural systems, several of which have no analogue in genetic transmission.

Variability in the modes of CT has been elaborated on from research in ethnoarchaeology, evolutionary psychology and anthropology, leading the basic forces of biased transmission to be supplemented by models such as “prestige-biased guided variation,” from evolutionary psychology (Henrich and Gil-White 2001:175), and “negative prestige-biased” transmission from historical archaeology and ethnoarchaeology (Mills 2008:249). It is likely that the above fields will continue to illuminate the complexity of CT processes as more case studies are added to the CT repertoire.

3.2. Archaeological Applications of CT Theory

Modern applications of CT theory in archaeology have begun to explicitly test the presence/absence of CT processes through a range of techniques. Methods include cladistics or phylogenetic analysis (Buchanan and Collard 2008; Buckley 2012; Collard and Shennan 2000; Collard et al. 2006; Darwent and O’Brien 2006; Eerkens et al. 2006; Larsen 2011; Lyman and O’Brien 2000; Matthews et al. 2011; Moylan et al. 2006; Tehrani and Collard 2002, 2009; Tolstoy 2008), network analysis (Cochrane and Lipo 2010a; Lipo 2006), and applications of neutral theory (Bentley and Shennan 2003; Kohler et al. 2004; Lipo and Eerkens 2008; Lipo et al. 2006; Neiman 1995; Shennan and Wilkinson 2001; Shennan and Bently 2008; Steele et al. 2010). The aforementioned methods deal largely with group-level cultural dynamics and are borrowed from evolutionary biology. A method concerned with individual-level processes is ethnoarchaeology (Bowser 2000; Bowser and Patton 2008; Chernela 2008; Degoy 2008; Gosselain 2008; Herbich 1987; Herbich and Dietler 2008; Wallaert 2008). This approach has the ability to observe transmission processes as they are occurring at the individual level and to apply such knowledge to explanation of resultant group-level variation through the study of material culture in an ethnographic setting.
3.2.1. Individual-level CT

Ethnoarchaeological studies aim to understand processes in the present that lead to patterns observed by archaeologists in the past. Ethnoarchaeology has begun to develop models of CT that can be tested by the archaeological record. Herbich and Dietler’s (2008, see also Herbich 1987) work among the Luo of Kenya tested the assumption that ceramic variability is a function of post-marital residence. Developed by “ceramic sociologists” in the 1960s/70s (see Deetz 1965; Hill 1970; Longacre 1970), this model states that, assuming mother-to-daughter (vertical) transmission at the individual level, patrilocal residence should result in ceramic heterogeneity (because women move to their husbands’ village after marriage and take their ceramic style with them) and matrilocal residence should result in ceramic homogeneity (because women stay in the same village after marriage where they originally learned pottery manufacture). Herbich and Dietler’s (2008) research demonstrates how ceramic homogeneity can result from a pattern of patrilocal residence. The study identified post-marital ceramic design transmission processes from mothers-in-law to their respective daughters-in-law, a pattern of oblique transmission. Through conformity to the mother-in-law, ceramic design becomes homogenized within the village, leading to increased heterogeneity of “micro-styles” between villages (Herbich and Dietler 2008).

Conformity to ceramic design leading to village homogeneity has also been observed in southwestern Niger (Gosselain 2008), southern Fiji (LeBlanc 2011), and northern Cameroon (Wallaert 2008). In southwestern Niger, transmission is primarily vertical, with half of potters learning the process after post-marital movement to a different village (Gosselain 2008). In Fiji, transmission flows in vertical, oblique, and horizontal directions where a master potter is largely responsible for teaching potters in a collective setting (LeBlanc 2011). In northern Cameroon, conformity is enforced through punishment for potters within the Dii community (Wallaert 2008). Here, young girls learn pottery manufacture from their mothers through vertical transmission. Judgment of the finished product and punishment ensure that potters conform to the norm, a pattern that confirms predictions made by cognitive psychologists about the predominance of conformity as a force of CT (McGuigan et al. 2012; Wallaert 2008).
Several other ethnoarchaeological studies have further illuminated CT patterns at the individual level. Chernela (2008) has observed the CT of grating boards (used in food preparation) among Baniwa speakers of Venezuela, Colombia, and Brazil. Distribution of grater boards follows marriage alliances throughout the region. Motifs on the boards are transferred from father to son, during which sons copy designs in a form of “collective submission” (Chernela 2008:146). These boards are then moved between community boundaries by women when they relocate to their husbands’ villages after marriage (Chernela 2008). In this case, vertical transmission at the individual level results in a pattern of heterogeneity of board design within villages and homogeneity of design between villages at the group level. Other studies suggest that in instances where vertical mother-to-daughter transmission of pottery dominates, potters manipulate designs to signal in-group/out-group affiliation, leading to patterns of homogeneity within groups and heterogeneity between groups (Bowser 2000; Bowser and Patton 2008).

Ethnoarchaeological studies reveal that several individual-level processes of CT can lead to similar group-level outcomes. For archaeological interpretation, this means that we may never be able to definitively identify individual-level processes. Despite this, ethnoarchaeology has the potential to provide archaeology with predictive models of CT. This requires that more quantitative analysis on attribute data be performed and compared cross-culturally to determine how the content, context, and mode of transmission lead to patterns of artifact variation.

3.2.2. Group-level CT

Given that archaeological assemblages qualify as group-level phenomena, methods used to test for patterns of CT are those amenable to group-level processes, largely derived from population genetics and evolutionary biology. Both cultural and genetic variants are created through transmission processes, meaning both have evolutionary histories amenable to phylogenetic analysis, a method requiring that variants evolve through descent with modification and have hierarchical relationships (Darwent and O’Brien 2006; O’Brien et al. 2008). Cladistics or phylogenetic analysis is a graphical method for determining relationships between ancestral and derived characters based on the null model that new taxa (characters) arise from the bifurcation
of existing taxa (for explanation and review see Collard et al. 2008). Such methods have been employed in a range of other disciplines such as linguistics (Atkinson et al. 2008; Gray et al. 2009; Greenhill et al. 2010; Rexova 2003) and stemmatics (the study of ancient texts) (Barbrook et al. 1998; Howe and Windram 2011; Ross et al. 2013; Skelton 2008).

Several phylogenetic studies aim to identify the relative degree of phylogenesis versus ethnogenesis in the archaeological past (Borgerhoff Mulder et al. 2006; Collard and Shennan 2000; Collard et al. 2006, 2008; Moore 1994; Tehrani and Collard 2002, 2009). Phylogenesis (also referred to as branching or demic diffusion) refers to situations in which similarities and differences between cultures result from “a combination of predominantly within-group information transfer and population fissioning,” leading to a pattern of vertical transmission at the group-level (ancestor to descendent groups) and strong phylogenetic signal (Collard et al. 2006:53). Ethnogenesis (also referred to as blending or cultural diffusion) refers to situations in which a “new cultural assemblage arises through the blending of elements of two or more contemporaneous assemblages” (Collard and Shennan 2000:89). Ethnogenesis leads to a pattern of horizontal transmission at the group level best displayed by networks or reticulated graphs (Borgerhoff Mulder et al. 2006; Collard et al. 2006). Hypotheses concerning the degree to which cultural assemblages arise from either process are assessed by determining how well archaeological data fit the structure of a bifurcating tree.

Several studies have approached patterns of group interaction by analyzing textile design and production using phylogenetic methods (Buckley 2012; Larsen 2011; Matthews et al. 2011; Tehrani and Collard 2002, 2009; Tolstoy 2008). Tehrani and Collard (2002, 2009) have used phylogenetic analysis of Turkmen textile design dating to the 18th century to test the hypothesis that ethnogenesis is the dominant process in cultural evolution. In this analysis, textile design motifs represent the characters, while taxa are represented by the “totality of design types expressed in a set of weavings” (Tehrani and Collard 2002:447). The degree to which the data fit the tree model is assessed through the Consistency Index (CI) and bootstrapping, where CI refers to the measure of homoplasy (independent invention) observed in the data and bootstrapping...
identifies that probability that the tree diagram represents the true tree (Collard et al. 2008). Results indicate that the data fit the tree model well, with a CI value of approximately 70%, indicating that phylogenesis was the predominant process leading to observed textile design variation. In a second study, the authors test the prediction that phylogenesis at the group level infers vertical transmission at the individual level by comparing cladistic results to ethnographic data on textile learning processes (Tehrani and Collard 2009). Ethnographic data suggest that vertical transmission occurs during childhood, but horizontal and oblique processes influence transmission at later life stages. However, social norms prohibit designs from being transferred between groups, leading to homogeneity within and heterogeneity between groups, or vertical transmission at the group level (Tehrani and Collard 2009). In a follow-up study on the same textile assemblage, Matthews and colleagues (2011) use Bayesian phylogenetic methods to show that different aspects of textile design have different transmission histories, further complicating patterns of artifact transmission. This study highlights the observation that the content of what is passed within and between generations can affect the conclusions drawn from the analysis; such results support findings from ethnoarchaeological studies discussed above.

Aside from textiles, several other categories of material culture have been studied through a CT perspective using the method of phylogenetic analysis. Studies explore the evolutionary histories of projectile points (Buchanan and Collard 2008; Darwent and O’Brien 2006; Eerkens et al. 2006; O’Brien et al. 2012), ceramics (Cochrane 2004, 2008; Collard and Shennan 2000; Harmon et al. 2006; Neff 2006), and barbed points (Riede 2008). These studies suggest that different types of material culture have different transmission histories, which must be determined on a case-by-case basis. (Collard et al. 2006).

The degree to which phylogenetic analysis accurately predicts processes of transmission in the archaeological record has been debated (Borgerhoff Mulder et al. 2006; Boyd et al. 1997; Eerkens et al. 2006). Boyd et al. (1997) examine the role of descent in cultural evolution and the degree to which cultural variants are amenable to phylogenetic analysis. They provide several hypotheses concerning the hierarchical structure of “cultures”, ultimately composed of a “core” that resists recombination and
smaller unobservable elements (memes) that are invented or diffused too rapidly for historical relationships among them to be identified through phylogenetic analysis. Boyd et al. (1997) appear to take the cultural meme/genetic gene analogy very literally, ultimately arguing that because current cultural phylogenetic analysis takes phenotypic traits as the unit of analysis and not the “mental representations that are stored and transmitted” (i.e. memes), true patterns of cultural descent are impossible to trace (Boyd et al. 1997:377).

Borgerhoff Mulder et al. (2006) argue against the assumption that phylogenetic signal or tree structure automatically suggests vertical transmission (phylogenesis). They suggest high goodness-of-fit measures (RI and CI) are just as likely to “reflect a tendency for suites of correlated traits to be borrowed among closely related neighbouring societies as a packet,” as they are to reflect vertical transmission. They propose that other statistical techniques, such as ML and Bayesian inference be used to estimate likelihoods of all trees and provide confidence intervals around branches. They propose that a more adequate means of assessing CT of cultural traits is to produce expected distributions of trait frequency under varying modes of transmission, which can be accomplished through computer simulation (Borgerhoff Mulder et al. 2006). Ultimately, Borgerhoff Mulder et al. (2006) urge for caution to be maintained when interpreting phylogenetic trees and for independent evidence to be evaluated alongside such results.

Noting that phylogenetic analysis does not always reflect or interpret the degree to which bias plays a role in transmission processes, Eerkens et al. (2006) use computer simulation to determine the degree to which guided variation, conformist bias and indirect bias are accurately reconstructed through cultural phylogenies. They determine strength of phylogenetic signal through tree length (TL) and CI, which are inversely and strongly correlated. Results from simulations of guided variation suggest that when individuals experiment without direction, variation increases and cladistics becomes less useful because of low phylogenetic signal in the data. However, when experiment becomes directional, individuals increasingly arrive at the same result, decreasing variation and increasing phylogenetic signal as interpreted through high CI and low TL values (Eerkens et al. 2006). These results could be misinterpreted as vertical
transmission, suggesting that CI and TL values may not be the most appropriate for determining strength of phylogenetic signal in “true” vertical transmission. Results from simulations of conformist transmission and indirect bias (i.e. “prestige-bias”) lead to similar overall patterning in that variation is decreased from each process, leading to high CI and low TL values. However, indirect bias produces a slightly stronger phylogenetic signal than conformist bias (Eerkens et al. 2006:179). Overall, the authors suggest that different biased CT processes can lead to similar strengths of phylogenetic signal in cladistic analysis. In the second part of the study, two groups of projectile points from the Great Basin were analyzed through phylogenetic analysis. A previous study on the same data set (Bettinger and Eerkens 1999) suggested that covariation among variables in one group (Owens Valley Rosegate Points) were the result of guided variation, with the second group (Monitor Valley Rosegate points) influenced by conformist or indirectly biased transmission (Bettinger and Eerkens 1999). In contrast, phylogenetic analysis of the same data set indicated an absence of phylogenetic signal (Eerkens et al. 2006). Eerkens and colleagues (2006) explain this discrepancy in terms of varying scales of analysis, with previous studies concerned with point types and the current studies’ use of individual projectile points. Others have advocated the importance of scale in phylogenetic analysis (Borgerhoff Mulder et al. 2006; Jordan and Mace 2008); an issue compounded by the fact that what exactly constitutes a cultural trait is still widely debated, as is the scale of analysis that should be considered (Pocklington 2006; Riede 2008).

An alternative or complementary method to phylogenetic analysis is network analysis. Networks are connected graphs with cycles used in evolutionary biology to represent relationships between intraspecific data or “relationships between genes sampled from individuals within a species” (Posada and Crandall 2001:38). This method allows for the representation of relationships that are not hierarchically structured (vertical transmission), but instead are the product of recombination or hybridization (horizontal transmission). Network analysis has been advocated (Borgerhoff Mulder et al. 2006) and employed (Cochrane and Lipo 2010; Lipo 2006; Riede 2008) to analyze patterns of inheritance in archaeological data in instances where cultural traits are believed to have been subject to horizontal transmission (or blending) between groups.
Lipo (2006) provides an example of network analysis through an examination of projectile points from the southeastern United States based on metric and morphological measurements. A network was created of the “linkages between taxa of the fewest differences in characters” (Lipo 2006:101). External data on temporal sequence is needed to root the graph. Overall, the graph appears to represent a chronological pattern in which populations diverge from one another, possibly as a result of geography or “isolation by density” (Lipo 2006:104).

The aforementioned group-level archaeological examples have mainly been concerned with exploring the descent history of individual artifact types or characteristics of those types through graphical means. Other studies explore CT through computer simulation and various statistical techniques. Eerkens and Lipo (2005) use statistical simulations of the coefficient of variation (CV) to determine expected baseline values for artifact variation. Acknowledging that humans cannot detect differences in line length below 3% (the Weber Fraction), they model the amount of variation that can be expected in unbiased and biased transmission with copy error built into the model. Results indicate that under unbiased transmission, CV increases over time due to the “imprecision in how humans are able to visually measure, remember, and replicate artifacts” (Eerkens and Lipo 2005:322). However, CV eventually slows down over time in this model. In biased transmission (i.e. conformist and prestige-biased transmission), the amount of variation is reduced depending on the strength of the bias.

Building on the Eerkens and Lipo (2005) approach, Hamilton and Buchanan (2009) also model variation expected under unbiased and biased transmission with the accumulation of copying errors. Under unbiased transmission, they find that the mean of the distribution drifts “negatively” over time, meaning that small variants remain small and large variants have an increasing probability of producing small variants. Under biased transmission “the total amount of variation that can occur at any one time is bounded by the frequency with which individuals choose to conform or copy prestigious individuals” (Hamilton and Buchanan 2009:60), leading to stabilization of variance through time. They test their model through an application to Clovis projectile points throughout North America and conclude that it represents an appropriate null model for CT of quantitative data.
Cochrane (Cochrane 2004, 2009) uses both phylogenetic analysis and CV measurements to understand CT processes in prehistoric Fiji from pottery attributes. Results track continuity and decline in transmission lineages (Cochrane 2004) and suggest that transmission biases may be responsible for periods of decreased variation in early prehistory (Cochrane 2009), with increases in variation likely attributable to a decrease in bias, resulting in increasing vessel diversity in the late prehistoric period. The above studies illustrate the potential of CT modeling.

Several other case studies as well as computer simulation research are beginning to tease out contributing factors to group-level cultural phenomena, including population size constraints (Edinborough 2009; Shennan 2013), and suggest that caution be maintained when using variant frequencies to interpret social learning processes (Steele 2009). Contextual information on economics, environmental, and sociocultural aspects of a study group should be interpreted alongside variant frequencies to ensure that multiple lines of evidence are pursued before conclusions are made regarding CT processes (Steele 2009); a call that has been taken up in recent studies (Kohler 2013, 2013; Shennan 2013). It is clear from the above group-level studies of CT that several factors can impact variant diversity and homogeneity, suggesting that hypotheses regarding CT include contextual information for groups under investigation.

A review of the CT literature, with specific regard to archaeological case studies, indicates the complexity with which humans learn and pass on information both within and between generations. Despite this, CT theory provides testable hypotheses that are useful for providing predictions and likely mechanisms of information transfer. While we may never be able to definitively know the unique individual-level processes that contribute to group-level patterns provided by the archaeological record, CT theory provides a testable framework to rule out possibilities, one study at a time.

3.3. Research Design

The above review of the CT literature paints a complex picture of the content, context, and mode of human CT that is framed by both psychological and cultural
processes interacting at varying scales of analysis. If archaeologists are to work towards understanding patterns of information transmission, testable hypotheses must be generated based on models derived from diverse disciplines including biology, psychology, anthropology, and ethnoarchaeology. CT theory will be used here to inform hypotheses and predictions about the transmission of Lapita design attributes.

3.3.1. Use of CT Tenants to Develop a Structural Approach to the Study of Lapita Ceramic Design

Lapita ceramic design is most notably used to answer questions of interaction and migration within the Lapita realm, relying upon the assumption that design attributes were passed within and between generations through social learning. Given this, it is reasonable to use the tenets of CT theory to inform research questions and study design. CT theory has indicated that information signalled by variation in ceramic design, among other artifact types, is dependent on factors such as population size, the number of potters who contribute design to the next generation, the direction with which design is passed on within and between generations, biases, and copy error, among others. More importantly, the CT literature has identified that the aspect of design being studied can impact the results of possible transmission mechanisms (Matthew et al. 2011), a result echoed through ethnoarchaeological research (Arnold 1983; Bowser 2000; Degoy 2008; Friedrich 1970; Gosselain 1992; Graves 1985; Hardin 1983).

CT theory informs the research design of this dissertation by first questioning the assumption that the sharing of elements and motifs provides the most useful measure of potter interaction. Second, the CT literature indicates that other attributes of design, such as structural application, need to be measured and compared to elements/motifs since the content of what is passed within and between generations may have varying transmission histories. Therefore, the element/motif and structural approach will be tested and compared under the following null hypothesis:

*The ways in which decorative ceramic design is classified into attributes does not impact the conclusions reached about Lapita archaeology when different attributes are compared.*
The difference, if any, in the conclusions drawn from using both approaches will be used to understand interaction within the Eastern Lapita Province and to determine the usefulness of this province designation. Use of CT theory to design the three case studies of this dissertation is outlined below, along with a discussion of CT-informed hypotheses and predictions.

3.3.2. Case Study 1: The Eastern Lapita Province

In the first case study, I analyze and compare elements/motifs and structural attributes of ceramic design within archaeological sites in the Eastern Lapita Province. While ceramic studies on element/motif and structural attributes of design have been undertaken, both in the Lapita realm and cross-culturally, rarely, if ever, are both methods compared. It is often assumed that the more design attributes two regions share, the more they interacted. While this may hold true in various circumstances, the CT literature has shown that this assumption may be falsified. Given that the analysis of elements and motifs between West Fiji, Lau, and Tonga have led to different conclusions regarding interaction within the region, structural attributes should be added and compared to determine if both methods produce similar results. If differences occur between conclusions reached using elements/motifs and structural attributes, it may be due to variation in social learning mechanisms, as CT theory predicts.

Hypotheses and Predictions

The null hypothesis to be tested in this case study is as follows:

*West Fiji, East Fiji, and Tonga do not differ in the distribution of elements/motifs or structural attributes of ceramic design during the Lapita Period.*

If this hypothesis were to hold true, I would predict the following:

1. The distribution of elements/motifs and structural characters of design should be similar between West Fiji, East Fiji, and Tonga.

If this hypothesis were to be rejected, I would predict the following:

1. West Fiji, East Fiji, and Tonga should differ in the distribution of elements/motifs and structural characters of design. The amount of
difference between each region should be greater than the difference within.

2. Given that structural design characters are used in this study, different conclusions concerning degree of Lapita interaction throughout West Fiji, Lau, and Tonga should result as compared to those garnered solely from element/motif analysis (i.e. Clark and Anderson 2009; Clark and Murray 2006; Cochrane and Lipo 2010). If elements/motifs and structural design attributes have different transmission histories, then the distribution of both should provide contradictory conclusions regarding similarity/dissimilarity between regions within the Eastern Lapita Province.

### 3.3.3. Case Study 2: A View from Outside

Studies of Lapita ceramic design have indicated that regional differences occur throughout the Lapita realm, leading to the demarcation of spatially distinct “Provinces” (Kirch 1997). In the second case study, I increase the sampling of Lapita ceramic assemblages to include those from both Southern and Western Lapita Provinces. Differences between provinces, in terms of ceramic design, are predominantly based on the presence/absence and/or frequency of elements and motifs. While knowledge of this variation is important, other aspects of design may signal different patterns of interaction and/or migration as suggested throughout the CT literature.

**Hypotheses and Predictions**

Based on previous studies in the Lapita region which identify distinct “Province” categories based predominantly on ceramic variability, I will test the following null hypothesis:

*The distribution of elements/motifs and structural attributes of Lapita design do not vary between the Eastern, Western, and Southern Lapita regions.*

If this hypothesis were to hold true, I would predict the following:

1. The distribution of elements/motifs and structural characters of design should be similar between the Western, Eastern and Southern Lapita Provinces.

If this hypothesis were to be rejected, I would predict the following:
1. If the Eastern Lapita Province represents a distinction from the west and south, then the distribution of elements/motifs and structural aspects of design from this region should differ from that observed for the Southern and Western Provinces.

2. If the Eastern Lapita Province represents a cohesive region, then variation in the distribution of both elements/motifs and structural design attributes within should be less than variation between Southern and Western Lapita Provinces.

3. If elements/motifs and structural design attributes have different transmission histories, then the distribution of both should provide contradictory conclusions regarding similarity/dissimilarity between the Eastern Lapita Province and Southern/Western Lapita Provinces. The results of structural analysis should not conform to previous conclusions reached on distinctions between Lapita provinces garnered through element/motif analysis.

3.3.4. Case Study 3: A View from Within

The third and final case study will take a smaller-scale approach to understanding design variation in the Lapita period by focusing on the Tongan archipelago, which is composed of three island groups – Tongatapu, Ha'apai, and Vava'u. Several additional archaeological sites will be analyzed to understand variation in both element/motif and structural attributes, allowing observation of change through time. A recent re-analysis of radiocarbon dates, short-lived wood charcoal dates, and U/Th dates on coral artifacts, through Bayesian modeling, indicates that Lapita settlers colonized Tongatapu by 2838 ± 8 calBP (2σ) (U/Th 11-36) and moved north into Ha'apai and Vava'u within 70-90 years (Burley et al. 2015). Given that the time scale from first Lapita settlement on Tongatapu to movement into Ha'apai and Vava'u is in the order of a few generations (Burley et al. 2015), analysis of ceramic design during this migration will shed light on variation, or lack thereof, during an unprecedented timescale in Lapita archaeology.

Hypotheses and Predictions

I will test the following null hypothesis:

*The distribution of elements/motifs and structural attributes of Lapita design do not vary between Tongatapu, Ha'apai, and Vava'u.*
If this hypothesis were to hold true, I would prediction the following:

1. The distribution of elements/motifs and structural characters should be similar throughout Tongatapu, Ha’apai, and Vava’u.

If this hypothesis were to be rejected, I would predict the following:

1. Ceramic design attributes should vary between Tongatapu, Ha’apai, and Vava’u.
2. Given that transmission of structural aspects of design is hypothesized to differ from the transmission of elements/motifs, results garnered from both approaches should differ.

3.4. Chapter Summary

This chapter has presented an overview of the theoretical focus of this dissertation, namely, cultural transmission (CT) theory. A brief literature review of CT theory was provided, with particular focus on archaeological applications. Approaches of applied CT theory were sub-divided on the basis of individual and population-level perspectives, with a discussion of how such levels are identified through the archaeological record. Methodological use of CT theory to inform Lapita ceramic design analysis was also indicated. Finally, the relevance of CT theory to the development of a structural approach to Lapita ceramic design analysis was discussed, along with CT-derived hypotheses and predictions for each of the three case studies in this dissertation.
Chapter 4.

Methodology for a Structural Approach to Lapita Ceramic Design Analysis

Theoretical concepts on the transmission of ceramic design indicate that application and layout are important aspects to analyze when testing hypotheses of interaction and migration. While attempts have been made to record and analyze certain attributes related to design structure, a comprehensive methodology is lacking. To address this gap in Lapita design analysis, I outlined the methods taken to develop a structural approach, with emphasis on objectivity and applicability throughout the Lapita realm.

In order to identify appropriate attributes for analyzing design structure, it was necessary to consult previous studies of archaeological ceramic design. Ideas on attribute selection were drawn from studies on structural ceramic design analysis in archaeological regions outside of the Lapita realm (Carlson 1961; Friedrich 1970; Hegmon 1994, 1995; Hegmon and Kulow 2005; Shepard 1956; Van Keuren 1999). Ethnoarchaeological studies from a wide range of study regions and temporal periods further guided the selection process (Bowser 2000; Bowser and Patton 2008; David et al. 1988; Hegmon 1992, 2000; Herbich 1987). Finally, in order to tailor the approach to Lapita archaeology, the history of ceramic design analysis was first reviewed, specifically in reference to the Eastern Lapita Province (Anson 1983; Best 1984; Green 1979, 1990; Mead et al. 1975; Poulsen 1987). From these three main study areas, attribute categories were narrowed to enable efficient recording for available archaeological ceramic assemblages. Archaeological sites were sampled to maximize representation from the Eastern Lapita Province, while at the same time enabling more in-depth and outside comparison to determine the practicality of this province designation. Below I outline the attributes chosen for analysis, along with the microscope techniques used to
record and measure such attributes. A discussion of sampling strategy and archaeological sites is also provided, along with a discussion on statistical methodology.

4.1. Attributes

In total, 17 attributes were chosen for analysis. These were divided into continuous and nominal categories. Descriptions of attributes are outlined in Table 4.1. Continuous variables consist of dentate width, length, density, spacing, depth, area, surface area, volume and the number of elements/motifs/processes per sherd. Nominal variables consist of zone direction, frequency of elements/motifs/processes per sherd, infilling of motifs, symmetry, lime filling and slip.

4.1.1. Continuous attributes

Structural continuous attributes that could be measured were sought in addition to nominal attributes as a means of quantifying design complexity and to enable small sherds to be analyzed. Anyone performing a visual inspection of pottery design from the Eastern Lapita region, even by those unfamiliar with Lapita ceramics, can easily distinguish those originating in West Fiji and those from Tonga based on the density of application of design elements and motifs (Burley et al. 2002). When East Fiji is added into the mix, design execution appears to mirror that of Tongan sherds, less dense than designs applied on West Fijian sherds and sherds found in regions outside of the Eastern Lapita Province. For this reason, attributes that could account for this variation in design execution were sought, resulting in the use of dentate density, and recording of the spacing between individual dentate teeth and dentate-stamped tool impressions.

Microscope techniques

Recent advances in microscopy now allow for more accurate measurements of design on sherds once considered too small for analysis and have the potential to enable structural ceramic attributes to be quantified and compared more easily than was previously possible. Two microscopes were utilized for the measurement of continuous variables. The first was a Leica MZ6 modular stereomicroscope (hereafter referred to as
the Leica). Use of this microscope was provided by the Department of Archaeology at Simon Fraser University. The Leica uses incident light illumination and has a 6.3:1 zoom. This microscope was used to measure dentate width, length, spacing 1 and 2, along with density. Samples were magnified using 6.3-8.0x lenses, resulting in a field diameter of 33.3-26.3 mm. Resulting images were imported into Adobe Photoshop © to record measurements.

Dentate density was measured by placing a digital 1 cm² square onto the magnified photograph and subsequently counting the number of individual dentate-stamped lines present within the square (Fig. 4.1). The square was moved around the entire design surface to ensure that the highest density value was recorded. For length and width measurements of dentate stamp teeth, several individual dentate tooth impressions were chosen per sherd. The shortest side was recorded as the width, with the longest recorded as length (Fig. 4.1). The location of the teeth were chosen to maximize representation from several design regions on each individual sherd. Several locations were chosen so that the mean of the six tooth impressions could be calculated before any statistical tests were run, giving a more balanced measure of dentate size throughout the sherd. Dentate spacing was divided into two categories: spacing between individual dentate tooth impressions and spacing between dentate lines (Fig. 4.1). For each dentate tooth impression chosen for a length/width measurement, the space between the tooth impression and impressions to either side was measured, along with the space to the nearest dentate-stamped line (Fig. 4.1).
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zones</td>
<td>The direction of application (i.e. does the zone divide the design space into horizontal and/or vertical segments) (Fig. 4.6)</td>
</tr>
<tr>
<td>Elements</td>
<td>Code based on Chiu and Sand (2005), but with additional descriptions(categories added (see Table 3)</td>
</tr>
<tr>
<td>Motifs</td>
<td>Code based on Mead (1975) and Poulsen (1987) categories</td>
</tr>
<tr>
<td>Infilling of motifs</td>
<td>Presence/absence of elements placed within known motif categories</td>
</tr>
<tr>
<td>Process</td>
<td>Relationships between motifs as outlined in Sharp (1988). Refers to the process applied to elements in order to create a motif (Fig. 4.5)</td>
</tr>
<tr>
<td>Symmetry</td>
<td>Description of the motion of element/motif repetition. Notation system used is that of Washburn and Crowe (1988).</td>
</tr>
<tr>
<td>Lime-filled</td>
<td>Indication of the presence/absence of lime used to fill dentate impressions</td>
</tr>
<tr>
<td>Slip</td>
<td>Indication of the presence/absence of slip applied to the vessel surface</td>
</tr>
<tr>
<td>Dentate length</td>
<td>Length of a single dentate tooth impression (Fig. 4.1, 4.2)</td>
</tr>
<tr>
<td>Dentate width</td>
<td>Width of a single dentate tooth impression (Fig. 4.1, 4.2)</td>
</tr>
<tr>
<td>Dentate depth</td>
<td>Depth of a single dentate tooth impression (Fig. 4.3)</td>
</tr>
<tr>
<td>Dentate area</td>
<td>Area of a single dentate tooth impression (Fig. 4.4)</td>
</tr>
<tr>
<td>Dentate surface area</td>
<td>Surface area of a single dentate tooth impression (Fig. 4.4)</td>
</tr>
<tr>
<td>Dentate volume</td>
<td>Volume of a single dentate tooth impression (Fig. 4.4)</td>
</tr>
<tr>
<td>Dentate spacing 1</td>
<td>Measurement of space between a single dentate tooth impression and those to either side (Fig. 4.1)</td>
</tr>
<tr>
<td>Dentate spacing 2</td>
<td>Measurement of space between a single dentate tooth impression and the closest dentate-stamped line (Fig. 4.1)</td>
</tr>
<tr>
<td>Dentate density</td>
<td>Number of dentate-stamped lines within a 1cm² area (Fig. 4.1)</td>
</tr>
</tbody>
</table>

Table 4.1. Attributes used to analyze Lapita ceramic design.
A second microscope was used in order to gain more insight into the size and shape of dentate impressions. This was the Olympus LEXT 4000 (hereafter referred to as the LEXT), a laser scanning confocal microscope designed for nanometer level 3D imaging. This microscope has a dual confocal system and a 405 nm laser, which
enables a magnification range of 108x-17280x. Surface measurements derived from the laser are presented in real-color 3D dual confocal images, along with other presentation modes. From these images, the technician can identify points on the sample to be measured directly. The Advanced Material and Process Engineering Laboratory at UBC generously provided use of this microscope. This tool is often used in lithic use-wear analysis (Evans et al. 2014; Key et al. 2014; Stemp et al. 2013), but has remained underutilized in ceramic design analysis. An exception is the work of Artal-Isbrand et al. (2011) and Artal-Isbrand and Klausmeyer (2013), who use laser scanning confocal microscopy to analyze tool use and production sequence for relief and contour lines on Greek red-figure vases. Although generally used for relief-based decorative analysis, laser scanning confocal microscopy has the potential to be applied to decorated ceramics and other forms of material culture where information regarding the size and application of design is sought. The use of this technology to quantify structural ceramic design is demonstrated here.

This instrument was predominantly chosen for its ability to measure the shape of single dentate tooth impressions in a non-destructive manner. Attributes that were measured include dentate length, width (Fig. 4.2), depth (Fig. 4.3), surface area, area, and volume (Fig. 4.4). Samples were observed with a 5x objective lens, providing a total magnification of 108x. Given the limited field of view (2560 x 2560 µm) and stage configuration, only individual dentate tooth impressions, instead of complete dentate tool impressions, could be viewed and measured. This also required that samples be, on average, less than 5cm and have a limited curvature in order to fit under the objective lens. Three dentate teeth were measured per sherd. The location of the teeth was chosen to maximize representation from several design regions on each individual sherd. For similar reasons to the Leica measurements, this was done to achieve a representative sample from each sherd.
Figure 4.2. Image provided by the Olympus LEXT 4000 laser scanning confocal microscope of ceramic sherd K1-5 from Kavewa, Fiji at a magnification of 108x. Arrows represent length (horizontal) and width (vertical) measurements of a single dentate tooth impression.
Figure 4.3. Image provided by Olympus LEXT 4000 of ceramic sherd Voro10:191 from Vorovo, Fiji magnified at 108x. Colours represent differential depth measurements, which can be accurately measured through the corresponding software, as seen in the bottom left corner.
Figure 4.4. Image provided by Olympus LEXT 4000 of ceramic sherd To2-2749 from Nukuleka, Tonga. Through corresponding software, the area, surface area, and volume of a given dentate-stamped tooth can be measured as shown in the bottom left corner.
It is important to note that the attributes which refer to dentate size and spacing between individual dentate teeth, while important measures of design structure, are indicative of the tools used to produce design. While these tools have yet to be identified in the Lapita literature (Ambrose 2003, 2012), it is possible that regardless of the form, these tools could have been made by different individuals than those who applied the tools to the vessel surface. In addition, such tools may have also been traded within and between communities of potters. Despite this, the goal of this structural analysis is not to identify individual potters, as this endeavour has been questioned in the ceramic literature (Crown 2007; LeBlanc 2011), but to identify regions of stylistic homogeneity. For this reason, attributes that relate to tool size and spacing are worthy of consideration, as these aspects of Lapita ceramic design may have been subject to variation during the mechanisms of cultural transmission.

A limitation of analyzing these attributes is that they are impacted by the process of clay type as well as by the process of firing post-design application. These factors impact the degree to which the clay shrinks, thereby altering the three-dimensional shape of dentate design application. No experimental studies have been conducted for Lapita archaeology to identify the precise impact such factors have on design execution and resulting design elements and motifs. Experimental studies on firing conditions (Irwin 1985; Kirch 1997) however, suggest that Lapita pottery was fired in low-intensity conditions, resulting in firing temperatures somewhere between 600-750°C (Dickinson 2006; Kirch 1997, 2000). This, along with the assumed predominant use of sand as a tempering agent (Dickinson 2006; Kirch 1997), decreases the uncertainty that such factors will impact the extent to which differences in the above attributes can be considered indicative of different pottery-manufacturing groups or different mechanisms of cultural transmission.

4.1.2. Nominal Variables

Although the measurement of design application is an important element to a structural approach, such an approach is not complete without analysis of nominal attributes that are specific to the study region. Despite concerns raised over the recording and description of design elements and motifs, particularly within the Lapita
region, such aspects of design are an important part of a comprehensive structural approach. They are also an aspect of design that needs to be compared to structural variables in order to parse out difference, if any, in transmission mechanisms. For this reason, I include the analysis of elements and motifs here, along with the identification of the processes applied to elements (Table 4.1). Aside from traditional recording of elements and motifs, a structural approach should also include attributes that describe the layout of design fields, as well as parameters that are specific to a design repertoire. In the case of Lapita ceramics, the proposed structural approach used here includes the recording of the direction of vessel zones, symmetry notation, presence/absence of lime filling, infilling of motifs, and slip.

Elements and motifs were recorded based on previous lists compiled for the Lapita region. Elements were identified according to the most recent coding system developed by Chiu and Sand (2005). An issue with this system is that it does not take into account the direction of element application. For instance, element 6 is a dentate-stamped curve (Chiu and Sand 2005:138). This definition does not indicate where the inflection point on the curve is positioned, either north, south, east, or west. The direction impacts how the element is viewed by the recorder. For this reason, the Chiu and Sand (2005) notation system required updating to reflect changes in element direction (Table 4.2). Motif codes were based on previous motif lists collected specifically for the region under study. For most Lapita ceramics that were examined, the Poulsen (1987) list was consulted first for consistency purposes. If a motif could not be identified by this system, then Mead and/or Anson lists were consulted (Anson 1983; Mead et al. 1975). In order to increase comparability across sites, element, motif, and process type were recorded once per sherd and Poulsen’s (1987) motif categories were simplified into letter categories. For example, a motif labelled A4 or H3 in Poulsen’s (1987) motif code, were labelled as motif A or H, respectively. In order to describe how elements are combined to form motifs, Sharp’s (1988) notation system was used. This system requires the recorder to identify the processes, or movements, that express the relationships between elements and motifs as outlined in Sharp (1988). Processes include such movements as repetition, half-drop mesh, and mirror-reflection, among others (Fig 4.5). Both the number and frequency of elements, motifs, and processes per sherd were recorded for analysis.
The direction of vessel zone (Fig. 4.6) was recorded here to first identify if a sherd had evidence of zone patterning and, if so, to describe if that zone was positioned either horizontally, vertically, or showed evidence of both. Lapita pottery has been recognized to contain complex designs within clear visual zones, often partitioned through the use of single or double dentate-stamped lines (Mead et al. 1975). To further describe the layout of design, symmetry notation was recorded. Symmetry, as it is used here, refers to the motion of motif repetition. The notation system used is that of Washburn and Crowe (1988), who have produced a handbook of standard procedures to follow when analyzing symmetry. They define symmetry as it is used in geometry to mean a “rigid motion (Crowe 2004:3) that creates a pattern (Washburn and Crowe 1988). They outline plane pattern symmetries, which refer to patterns whose symmetry occupies portions of the plane or a surface that can be considered planar when made flat (i.e. a ceramic vessel). They describe finite patterns (those that are not repeated) as well as one-dimensional and two-dimensional repeated patterns. One-dimensional refer to those that are translated in one direction only, as compared to two-dimensional patterns which are translated in two directions. They adopt a four-symbol notation system, originally developed by Russian crystallographers, which allows for standardization and simple comparison of results across studies. By following the flow-charts provided in the handbook, the researcher can easily determine the four-symbol code that best describes a given symmetrical pattern, offering a relatively objective way in which to analyze designs that can easily be repeated and applied cross-culturally. Aside from zone direction and symmetry, there are three attributes that relate specifically to the Lapita design repertoire: lime filling, motif infilling, and slip. The presence of lime and slip was based on visual inspection. The presence of motif infilling was determined by consulting motif list inventories to find the appropriate motif and then determining, based on visual inspection, if additional elements were added within the motif.
<table>
<thead>
<tr>
<th>Shape</th>
<th>Design Element</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight horizontal</td>
<td>Dentate-stamped</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.1</td>
</tr>
<tr>
<td>Straight vertical</td>
<td>Dentate-stamped</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.2</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.2</td>
</tr>
<tr>
<td>Straight angled in a NE direction</td>
<td>Dentate-stamped</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.3</td>
</tr>
<tr>
<td>Straight angled in a SE direction</td>
<td>Dentate-stamped</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.4</td>
</tr>
<tr>
<td>Straight angled in a SW direction</td>
<td>Dentate-stamped</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.5</td>
</tr>
<tr>
<td>Straight angled in a NW direction</td>
<td>Dentate-stamped</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.6</td>
</tr>
<tr>
<td>Curved horizontal inflection point North</td>
<td>Dentate-stamped</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.7</td>
</tr>
<tr>
<td></td>
<td>Rouletted curved</td>
<td>22.7</td>
</tr>
<tr>
<td>Curved horizontal inflection point South</td>
<td>Dentate-stamped</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.8</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.8</td>
</tr>
<tr>
<td>Curved vertical inflection point East</td>
<td>Dentate-stamped</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.9</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.9</td>
</tr>
<tr>
<td>Curved vertical inflection point West</td>
<td>Dentate-stamped</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Impressed</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>Appliqué</td>
<td>21.10</td>
</tr>
<tr>
<td></td>
<td>Rouletted</td>
<td>22.10</td>
</tr>
<tr>
<td>Circle</td>
<td>Appliqué circle (if single)</td>
<td>21.11</td>
</tr>
<tr>
<td>Square</td>
<td>Appliqué square (if single)</td>
<td>21.12</td>
</tr>
<tr>
<td>Appliqué</td>
<td>Appliqué</td>
<td>21</td>
</tr>
<tr>
<td>Roulette</td>
<td>Roulette</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 4.2. Extension and variation on Lapita design elements outlined in Chiu and Sand (2005). These are used to construct structural rules as outlined in Sharp (1988) and shown in Appendix A.
Figure 4.5. Photo of ceramic sherd from the Lapita site in New Caledonia. Orange arrow indicates the process of half-drop mesh, while the red arrow represent the process of repetition. Both also represent the process of intersection because there is no visible space between elements.
Figure 4.6. Photo of ceramic sherd 221 from the Lapita site in New Caledonia. The design zone is separated into two horizontal zones through the use of a single horizontal dentate-stamped line as indicated by the arrow.

4.2. Archaeological Ceramic Assemblages

The purpose behind developing a structural approach to Lapita ceramic design analysis is to be able to more objectively describe and measure variation in design application within the Eastern Lapita region in particular, and the entire Lapita realm more broadly. In order to do this, several archaeological sites were sampled from to represent three Lapita Provinces: Eastern Lapita, Western Lapita, and Southern Lapita. Samples from the Eastern Lapita Province were easily obtainable at the South Pacific Lab at Simon Fraser University. When possible, sites for which reliable dates were
available were chosen, along with areas within sites that were less likely to have been disturbed.

Once identified, 25 sherds in total for each Lapita Province were sampled. This number was determined through use of the following formula (Shennan 1997:367):

\[ n = \left( \frac{Z_a s}{D} \right)^2 \]

where \( n \) represents the estimated sample size that is required to estimate the population mean from a random sample, \( Z_a \) represents the standard error determined from a particular probability level, \( s \) represents an estimate of the population standard deviation as determine through a pilot sample, and \( D \) represents the tolerance level or the level at which it is acceptable to over/underestimate the population parameter. The standard error was set at 1.96, which is the 95% probability level that the population mean will be correctly identified through the sample size. The estimate of the population standard deviation was calculated from a pilot analysis. A pilot sample of 16 sherds from four regions within the Eastern Lapita Province (LeBlanc 2016) was first undertaken to test the ease and usability of the proposed structural approach. For each continuous attribute from this sample, the mean standard deviation was calculated to represent the \( s \) in the equation. The tolerance level was determined by choosing a mean within an interval of less than 50% of the estimated mean from the pilot sample. Calculations ranged from 15-23 as a sample size estimate. I choose 25 as my sample size for a conservative estimate.

The sampling procedure followed was simple random sampling; however, sampling situations outside of Simon Fraser University dictated whether this procedure was viable. In instances where time and funding was limited, a grab sample was collected whereby either I or a qualified Lapita archaeologist chose a sample of sherds from an excavation collection without first randomizing the collection catalogue, given time constraints. In order to be deemed appropriate for analysis, each sherd had to have at least four lines of clearly visible dentate stamped impressions. These samples were then analyzed for the attributes indicated above. While I do not pretend to assume that such samples sizes are ideal, the purpose of this research was predominantly to test the methods of analysis outlined here, rather than the analysis of complete Lapita ceramic
assemblages. Future research should address this issue by using increased sample sizes collected through stratified random sampling.

Of particular concern to sample size selection is the relationship, or lack thereof, between the number of elements and motifs visible per sherd and the size of the sherd. Therefore, it is first necessary to determine the degree to which sherd size correlates with element and motif frequency. If sherd size is related to the number of elements and motifs present on an individual sherd, then caution will be warranted for interpretation of element/motif analysis. A significant correlation would require that sherd size be controlled for, an issue that has yet to be addressed in Lapita ceramic design analysis. For this reason, the size of each sherd was determined by recording the length and width, parameters that can be easily controlled for during statistical analysis.

4.2.1. Microscope Analysis

Of the 25 sherds chosen for each Lapita Province, all were analyzed using the Leica for the following attributes: dentate length, width, spacing 1 and 2, and density. Six measures were recorded for each attribute, aside from dentate density, to provide a representative sample of dentate size from different areas of a single sherd. Given that these data points do not meet the assumption of independence, the mean of the six measures was tabulated and used for statistical testing (refer to section 4.2.2).

In order to further analyze the size and shape of individual dentate tooth impressions and to improve the precision and accuracy of measurements, a smaller sample of sherds was analyzed with the LEXT. Ten sherds were selected from the original random or grab sample of 25 in each Lapita Province. Attributes analyzed include dentate length, width, depth, area, surface area, and volume. The sherds were hand selected from the original random sample, based upon their size and shape suitability for use with the LEXT. Sherds were required to be, on average, 5 cm or less in length and width, and be relatively flat in order to fit under the objective lens. During pilot trials (LeBlanc 2016), six measures were recorded for each attribute to provide a representative sample of dentate size from different areas of a single sherd. After reflection on time constraints during pilot trials, it was decided that the number of data
points taken for each attribute would be decreased from six to three per sherd, followed by taking the mean.

4.2.2. Statistical Analysis

Statistical methods were used to compare diversity/homogeneity in attribute distribution within and between sample regions and to determine the impact of sherd size and dentate density in relation to other categorical attributes. Variation in distribution of continuous attributes was analyzed using ANCOVA. Normality was assessed by observation of histograms of attribute distribution and residuals to determine if ANCOVA or the nonparametric alternative, K-W, was the more appropriate test. Post-hoc tests were then performed to determine where differences, if any, existed. ANCOVA was also used to determine if attribute variation is greater within or between assemblages in order to understand how variation differs among attributes, especially between those categorized as structural versus element/motif. Given the large number of post-hoc tests performed, it was determined that the value at which statistical significance is determined be adjusted. The Benjamini-Hochberg method was used here because it is less conservative than the Bonferroni method and has greater power (Benjamini and Hochberg 1995; Benjamini 2010).

It was reasoned that the density of design application could influence the size, shape, and application of individual dentate tooth impressions. Based on this logic, the relationship between dentate density and each attribute was first assessed through a bivariate linear fit regression model. If a statistically significant relationship existed, then density was modeled as a covariate to control for its impact on the following attributes: dentate length, width, spacing 1 and 2, depth, volume, area, surface area, and the number of elements/motifs/processes per sherd. Along with dentate density, the size of each sherd, as indicated through length and width measurements, was also used as a covariate in the model, where appropriate, to control for impact on dentate size and shape outcomes. If any of these potential covariates produce a statistically significant relationship with any of the attributes, then they can be considered important predictors of such attributes and should be controlled for during analysis.
In addition to analyzing the number of elements, motifs, and processes per sherd, these variables were also analyzed using frequency counts. Frequency counts were assessed through comparison of contingency tables. Fischer’s Exact test was used to assess the significance between groups. However, due to violation of the assumption of independence of observations, such results must be interpreted with caution. All other categorical variables, including lime-filling, motif-infilling, direction of vessel zone, and symmetry, were compared using Fischer’s Exact test. Statistical tests were performed using either JMP ® 11 or SPSS ® 22.

4.3. Chapter Summary

This chapter has outlined the methodological approaches utilized in this dissertation. The main aim of this chapter is to provide a detailed description of the newly proposed structural approach to Lapita design analysis. This is the first time a comprehensive and measurable structural approach has been proposed in the Lapita literature, which also includes the analysis of elements and motifs. The approach has been streamlined to enable both small and large sherds from each region of the Lapita realm to be analyzed, with particular applicability to the Eastern Lapita Province. This is a region where the use of element/motif analysis falls short of describing similarity/dissimilarity in design application. The statistical approaches used to compare archaeological sites are also outlined. Overall, this chapter sets the stage for use of the newly proposed structural approach for Lapita archaeology in the following three case studies.
Chapter 5.

Case Study 1 – The Eastern Lapita Province

In order to apply the attributes listed in Chapter 4 and to test the usability of the proposed structural approach, three case studies were undertaken. The first case study analyzes ceramic sherds from the Eastern Lapita Province – the primary focus region of this dissertation – and is presented in this chapter. Methodologically speaking, the aim of this case study is to demonstrate the applicability of the new approach for quantifying diversity in design application and to determine patterns of difference, if any, between various regions within the province. If differences occur, the next aim is to determine if attribute categorization plays a role. Theoretically speaking, the purpose of this case study is to determine if structural attributes provide a pattern that is inconsistent with element and motif attributes. Such differences could be due to the way design is passed within and between generations through social learning, or may be due to issues in attribute recording systems and sample size, among other possibilities. If differences in attribute distribution does not occur within the Eastern Lapita region and between attribute categories, then the province category will hold true, as is currently defined. Below I outline the methods used to select archaeological samples, along with results from statistical analysis and a discussion of results.

5.1. Methods

As indicated in Chapter 4, 17 quantitative and qualitative attributes were recorded for each sample within the Eastern Lapita Province (Table 4.1). Each sample is composed of several archaeological sites from varying geographic and temporal periods. Individual archaeological sites that compose each sample will be discussed in detail, followed by a brief outline of attribute analysis.
5.1.1. Archaeological Samples

The Eastern Lapita Province was organized into four sample categories: Early Tonga, Late Tonga, West Fiji, and East Fiji (Fig. 5.1). These categories were chosen in order to analyze both spatial and temporal homogeneity/heterogeneity. Precise dating from coral branch files within Tonga enable sites to be categorized into Early and Late groups (Burley et al. 2012; 2015). The same cannot be said for Fiji, where dating techniques and results are currently being debated (Nunn and Petchey 2013; Burley et al. 2012). For this reason, Fiji is divided into West and East variants here in order to determine if ceramic design from East Fiji aligns more with sherds from West Fiji or Tonga.

.png

Figure 5.1. Island groups included in the Eastern Lapita Province. Arrows indicate archaeological sites analyzed in this study. Map by Vienna Chichi Lam.

Sherds from several archaeological sites were included in each sample (Table 5.1), with an emphasis on those where stratigraphic integrity could be established. Each assemblage catalogue was surveyed for ceramic sherds that had at least four lines of clearly visible dentate impressions. From these, 25 sherds were randomly selected for
Data for each attribute by archaeological site is provided in individual tables in Appendix A, along with summary tables of the raw data organized by case study in Appendix B, and a photo catalogue in Appendix C.

<table>
<thead>
<tr>
<th>Ceramic sample</th>
<th>Archaeological sites</th>
<th>N ceramic sherds analyzed with Leica</th>
<th>Sampling strategy</th>
<th>N used with LEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Tonga</td>
<td>Nukuleka (Burley et al. 2010)</td>
<td>25</td>
<td>Random</td>
<td>10</td>
</tr>
<tr>
<td>Late Tonga</td>
<td>Pukotala (Burley 1998; Burley et al. 1999)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Faleloa (Burley 1998; Burley et al. 1999)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Vaipuna (Burley 1998, Burley et al. 1999)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Mele Havea (Burley 1998; Burley et al. 1999)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tongoleleka (Burley 1998; Burley et al. 1999)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td>West Fiji</td>
<td>Bourewa (Nunn 2007; Nunn and Petchey 2013)</td>
<td>7</td>
<td>Grab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Kavewa</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Vorovoro (Burley 2010)</td>
<td>5</td>
<td>Random</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Naigani (Irwin et al. 2011)</td>
<td>8</td>
<td>Grab</td>
<td>4</td>
</tr>
<tr>
<td>East Fiji</td>
<td>Lakeba, site 196 (Wakea) (Best 1984)</td>
<td>25</td>
<td>Grab</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 5.1. Sample size used for Case Study 1. Samples were selected either through random sampling or through a grab sample for a total of 25 sherds per sample group. The number of ceramic sherds from each site that were analyzed using the Olympus LEXT 4000 are also indicated, with a total of 10 for each sample group. See Appendix A for detailed information on sherds, including catalogue numbers.

For Early Tonga, all 25 sherds come from the earliest site of Nukuleka. Nukuleka has been precisely dated through U/Th dating of coral artifacts, the earliest of which dates to 2838 ± 8 cal BP (U/Th 11-36), corroborated by a short-lived nutshell radiocarbon date (WK 23710) (Burley et al. 2012; 2015). Based on these early dates,

\(^1\) Aside from the sites of Bourewa, Naigani, and Lakeba, which were sampled outside of Simon Fraser University under time-constrained circumstances.
Nukuleka is thought to represent the founding settlement in Tonga (Burley et al. 2012, 2015) and provides a good site for comparing the earliest Lapita design in Tonga to both Fiji and later sites within the Tongan archipelago. Ceramics were sampled from the 2007 excavation assemblage (Burley et al. 2010), from units 9-13, 25, and 34-38, which are known to be the least disturbed. From these units, only levels 9-13 were initially sampled from because they pre-date assemblages from the Late Tongan sample used in this case study. Only 16 sherds from these levels fit the sampling criteria. In order to increase the sample size to 25, nine sherds were randomly selected from the entire catalogue, regardless of unit. From these 25 sherds, ten were chosen for use with the LEXT, based on size and shape suitability.

For Late Tonga, all sherds come from one of five sites on the island group of Ha’apai: Tongoleleka, Mele Havea, Vaipuna, Faleloa, and Pukotala. These sites were chosen in order to maximize representation from different areas around Ha’apai. Sites within this region were settled after initial migration to Nukuleka, within approximately 70-90 years and, therefore, represent a rare glimpse into ceramic change within three to four generations of initial landfall in Tonga (Burley et al. 2015). Sites consist of single hamlet-sized occupations situated on back-beach flats on the leeward coast of coral limestone islands (Burley et al. 1999). The earliest sites are Tongoleleka and Vaipuna, situated on Lifuka Island and ‘Uiha Island, respectively. The earliest date for Tongoleleka is 2720 ± 60 cal BP (CAMS 34561) and the earliest date for Vaipuna is 2690 ± 50 cal BP (CAMS 41526) (Burley et al. 2015). The three later sites in this analysis include Faleloa on Foa Island, Pukotala on Ha’ano Island, and Mele Havea on Ha’afeva Island. Initial occupation for Mele Havea is 2640 ± 50 cal BP (CAMS 41520), 2640 ± 60 cal BP for Pukotala (CAMS 41516), and 2600 ± 50 cal BP (CAMS 41530) for Faleloa (Burley et al. 2015). Given that the Lapita period lasts between 31-59 years, or two-and-a-half to three generations in Ha’apai (Burley et al. 2015), all dentate-stamped ceramics were considered appropriate for sampling, regardless of stratigraphic context. For this reason, the only sampling criteria for these sites was that a sherd needed to have at least four lines of clearly visible dentate-stamped impressions and be randomly sampled from the site catalogue. Five sherds were randomly sampled from each site for use with the Leica, for a total of 25 sherds. For the LEXT, two sherds from each site were selected, for a total of ten sherds, based on shape and size suitability.
The East Fiji sample is composed of 25 ceramic sherds from the site of Wakea on the island of Lakeba in the Lau Group of islands (Best 1984). Sherds from Lakeba were sampled from the University of Auckland. This site was chosen because it is thought to represent the earliest settlement in East Fiji, dated to approximately 2850 cal BP and provides the least disturbed context of all sites within this region (Best 1984). Given its early date, analysis of Lakeba sherds will help to shed light on the issue of whether Lapita ceramic design within East Fiji is more similar to West Fiji or Tonga. From the 25 sherds used for analysis with the Leica, ten were selected for analysis with the LEXT, based on shape and size suitability.

West Fijian sherds come from one of four sites: Bourewa, Naigani, Vorovoro, and Kavewa. Bourewa is located on the Rove Peninsula in southwestern Viti Levu. It has long been hypothesized as the founder settlement of Fiji (Nunn 2007), the earliest date suggesting settlement by 3000-3050 cal BP (but see Nunn and Petchey 2013). Sherds were chosen as a representative grab sample from the Fiji Museum given time-constrained circumstances. Thirty sherds were hand selected based on the criteria that they had at least four lines of clearly visible dentate stamping. From these 30 sherds, seven were randomly selected for use in this study. Recent excavations at the northern Fijian sites of Vorovoro and Kavewa suggest early and contemporaneous settlement with initial dates that are comparable to those for Bourewa and Naigani (Burley 2012). Both sites are situated off the northeast coast of Vanua Levu, with dentate-stamped ceramics indicative of early settlement in the region (Burley 2012; Burley pers. comm. 2014). For both Vorovoro and Kavewa, five sherds each were randomly selected from the excavation catalogue and chosen for analysis if there were at least four lines of dentate stamping present.

One issue with the above samples from East and West Fiji is that they differ temporally, making direct comparisons difficult. In order to address this issue, ceramic sherds from the West Fiji Lapita site of Naigani, situated on the eastern side of Naigani island off the eastern coast of Viti Levu, were sampled from the University of Auckland. Thirty samples were selected as a grab sample, ensuring that each had at least four lines of dentate stamping. From these 30, eight were randomly selected for use in this study. Settlement at Naigani dates to approximately cal 2850 BP, slightly later than other
Fijian samples used here, but contemporaneous to Lakeba (Irwin et al. 2011). Preliminary testing of Naigani sherds with those from Bourewa, Kavewa, and Vorovoro indicates that structural attributes do not differ significantly. Given this, Naigani was included in the West Fiji sample to decrease the probability that any attribute differences between West and East Fiji would be due to temporal factors. Ceramic samples from Kavewa and Vorovoro contained less sherds as compared to Bourewa and Naigani due to limited availability of suitable sherds from the decorated sherd catalogue. From the 25 West Fiji sherds used for analysis with the Leica, 10 were selected for analysis with the LEXT, based on shape and size suitability.

5.1.2. Attribute Analysis

Once selected, ceramic samples were analyzed for both structural and element/motif attributes. Attributes were divided into nominal and continuous categories. Nominal variables consist of zone direction, process type, presence/absence of motif infilling, lime, and slip, along with symmetry pattern and element/motif recording. Continuous attributes consist of dentate length, width, area, surface area, depth, volume, spacing (1 and 2), density, and the number of elements/motifs/processes per sherd. Dentate length, width, density, and spacing measurements were recorded using the Leica. Dentate length and width were also measured using the LEXT, along with dentate area, surface area, depth, and volume. Attribute descriptions are found in Chapter 4 (Table 4.1). Once recorded, attributes were compared between samples in order to determine similarity/dissimilarity in distribution. Statistical methodology is outlined in Chapter 4 (section 4.2.2). Results of statistical analysis are presented below.

5.2. Results

Before comparing continuous attribute distribution between groups, the relationship between attributes and dentate density, sherd length, and sherd width was first assessed through a bivariate linear fit regression model. Results indicate that for Leica attributes, density is a significant predictor of dentate length, width, spacing 1, and spacing 2 (Table 5.2). For LEXT attributes, density is also a significant predictor of dentate width, length, depth, area, surface area, and volume (Table 5.2). For this
reason, density is modeled as a covariate in subsequent attribute comparisons between sample groups.

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Dentate density</th>
<th>Sherd Length</th>
<th>Sherd Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate length</td>
<td>*0.001</td>
<td>0.3547</td>
<td>0.7811</td>
</tr>
<tr>
<td>Dentate width</td>
<td>*0.0013</td>
<td>0.9962</td>
<td>0.5325</td>
</tr>
<tr>
<td>Dentate spacing 1</td>
<td>*0.0460</td>
<td>0.1744</td>
<td>0.1604</td>
</tr>
<tr>
<td>Dentate spacing 2</td>
<td>*0.001</td>
<td>0.2158</td>
<td>0.4275</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEXT 4000 attributes</th>
<th>Dentate width</th>
<th>Sherd Length</th>
<th>Sherd Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate width</td>
<td>*0.0265</td>
<td>0.7825</td>
<td>0.7769</td>
</tr>
<tr>
<td>Dentate length</td>
<td>*0.0010</td>
<td>0.7180</td>
<td>0.8054</td>
</tr>
<tr>
<td>Dentate depth</td>
<td>*0.0167</td>
<td>0.4113</td>
<td>0.5244</td>
</tr>
<tr>
<td>Dentate area</td>
<td>*0.0451</td>
<td>0.5774</td>
<td>0.7383</td>
</tr>
<tr>
<td>Dentate surface area</td>
<td>*0.0064</td>
<td>0.8822</td>
<td>0.8336</td>
</tr>
<tr>
<td>Dentate volume</td>
<td>*0.0107</td>
<td>0.4161</td>
<td>0.8290</td>
</tr>
</tbody>
</table>

Table 5.2. P-values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 and LEXT 4000 attributes for the Eastern Lapita region. Significance is denoted by asterisk. Significance indicates that dentate density is a significant predictor of dentate attributes and must be controlled for in subsequent analysis.

Histograms for attribute distributions were viewed to assess data normality. For Leica attributes, only dentate spacing 2 required a natural log transformation, all other histograms were normally distributed. For LEXT attributes, both volume and surface area required a natural log transformation, all other histograms were normally distributed.

Before running the ANCOVA model for Leica attributes, the distribution of density between groups was first assessed. Through ANOVA, it was determined that dentate density differs significantly between groups ($p = 0.001$) (Fig. 5.2). Post-hoc tests indicate that West Fiji differs from all groups, whereas, Early Tonga, Late Tonga, and East Fiji do not differ (Table 5.3).
Figure 5.2. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Island group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

<table>
<thead>
<tr>
<th>Dentate Density $\alpha = 0.025$</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significantly different from</td>
<td>West Fiji $(p=0.001)$</td>
<td>West Fiji $(p=0.001)$</td>
<td>Early Tonga $(p=0.001)$, Late Tonga $(p=0.001)$, East Fiji $(p=0.001)$</td>
<td>West Fiji $(p=0.001)$</td>
</tr>
<tr>
<td>Not significantly different from</td>
<td>Late Tonga $(p=0.0507)$, East Fiji $(p=0.2092)$</td>
<td>Early Tonga $(p=0.0507)$, East Fiji $(p=0.4766)$</td>
<td>Early Tonga $(p=0.2092)$, Late Tonga $(p=0.4766)$</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.3. Post-hoc comparisons of density attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which groups differ significantly by indication of statistical $p$ values. Statistical significance is determined at an $\alpha$ level calculated using the Benjamini-Hochberg method.

The distribution of all Leica attributes differ significantly between groups, while controlling for dentate density (Table 5.4). Post-hoc tests indicate where differences lie (Table 5.5). For dentate length, only Late Tonga and East Fiji do not differ significantly; all other sample comparisons differ (Fig. 5.3). For dentate width, Early Tonga and West Fiji do not differ, nor do Late Tonga and East Fiji; all other comparisons differ (Fig. 5.4). For Spacing 1, the only comparisons that do not differ are Early and Late Tonga and Late Tonga and East Fiji (Fig. 5.5). For spacing 2, none of the comparisons differ.
significantly. The F ratios obtained from each attribute comparison are above 1, indicating that there is more difference between than within groups (Table 5.4).

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Dentate length</th>
<th>Dentate width</th>
<th>Dentate Spacing 1</th>
<th>Spacing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>p value</td>
<td>*0.0001</td>
<td>*0.0001</td>
<td>*0.0002</td>
<td>*0.0006</td>
</tr>
<tr>
<td>F-ratio</td>
<td>14.7618</td>
<td>7.9698</td>
<td>6.3008</td>
<td>5.3403</td>
</tr>
</tbody>
</table>

Table 5.4. P-values derived from comparison of means between the four sample groups in the Eastern Lapita Province using ANCOVA. Asterisk indicates statistical significance at $\alpha=0.05$. 
<table>
<thead>
<tr>
<th><strong>Leica MZ6 attributes</strong></th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dentate length α=0.042</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>Late Tonga (p=0.0150), West Fiji (p=0.0256), East Fiji (p=0.0006)</td>
<td>Early Tonga (p=0.0150), West Fiji (p=0.0001)</td>
<td>Early Tonga (p=0.0256), Late Tonga (p=0.0001), East Fiji (p=0.0001)</td>
<td>Early Tonga (p=0.0006), West Fiji (p=0.0001)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td></td>
<td>East Fiji (p=0.2851)</td>
<td>Late Tonga (p=0.2851)</td>
<td></td>
</tr>
<tr>
<td><strong>Dentate width α=0.033</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>Late Tonga (p=0.0009), East Fiji (p=0.0157)</td>
<td>Early Tonga (p=0.0009), West Fiji (p=0.0003)</td>
<td>Late Tonga (p=0.0003), East Fiji (p=0.0039)</td>
<td>Early Tonga (p=0.0157), West Fiji (p=0.0039)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>West Fiji (p=0.3682)</td>
<td>East Fiji (p=0.3043)</td>
<td>Early Tonga (p=0.3682)</td>
<td>Early Tonga (p=0.3043)</td>
</tr>
<tr>
<td><strong>Dentate spacing 1 α=0.033</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji (p=0.0322), East Fiji (p=0.0066)</td>
<td>West Fiji (p=0.0322), Late Tonga (p=0.0031)</td>
<td>Early Tonga (p=0.0322), Late Tonga (p=0.0031), East Fiji (p=0.0001)</td>
<td>Early Tonga (p=0.0006), West Fiji (p=0.0001)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga (p=0.2157)</td>
<td>Early Tonga (p=0.2157), East Fiji (p=0.1309)</td>
<td>Late Tonga (p=0.1309)</td>
<td></td>
</tr>
<tr>
<td><strong>Dentate spacing 2 α=0.033</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga (p=0.0545), West Fiji (p=0.7076), East Fiji (p=0.1300)</td>
<td>Early Tonga (p=0.0545), West Fiji (p=0.2015), East Fiji (p=0.6574)</td>
<td>Early Tonga (p=0.7076), Late Tonga (p=0.2015), East Fiji (p=0.3439)</td>
<td>Early Tonga (p=0.1300), Late Tonga (p=0.6574), West Fiji (p=0.3439)</td>
</tr>
</tbody>
</table>

Table 5.5. Post-hoc comparisons of attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical p values. Statistical significance is determined at different α values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The α values were determined using the Benjamini-Hochberg method.
Figure 5.3. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

Figure 5.4. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.
Figure 5.5. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

The distribution of all LEXT attributes differ significantly between groups, aside for depth, while controlling for dentate density (Table 5.6). Post-hoc tests indicate where differences lie (Table 5.7). For dentate width and volume, none of the comparisons differ. For dentate length, area, and surface area, West Fiji differs from all groups; no other comparisons differ (Figs. 5.6, 5.7, 5.8). The F ratio obtained from each attribute comparison is above 1, indicating that there is more difference between than within groups (Table 5.6).

<table>
<thead>
<tr>
<th>LEXT attributes</th>
<th>Dentate width</th>
<th>Dentate length</th>
<th>Dentate depth</th>
<th>Dentate area</th>
<th>Dentate surface area</th>
<th>Dentate volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$ value</td>
<td>*0.0422</td>
<td>*0.0001</td>
<td>0.1384</td>
<td>*0.0036</td>
<td>*0.0005</td>
<td>0.1352</td>
</tr>
<tr>
<td>F-ratio</td>
<td>2.7711</td>
<td>8.1441</td>
<td>1.8657</td>
<td>4.7566</td>
<td>6.4656</td>
<td>1.8834</td>
</tr>
</tbody>
</table>

Table 5.6. P-values derived from comparisons of means between the four sample groups using ANCOVA. Asterisk indicates statistical significance at $\alpha=0.05$. 


<table>
<thead>
<tr>
<th>LEXT attributes</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate width $\alpha$=0 comparisons significant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dentate length $\alpha$=0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0244$)</td>
<td>West Fiji ($p=0.0009$)</td>
<td>Early Tonga ($p=0.0244$), Late Tonga ($p=0.0009$), East Fiji ($p=0.0015$)</td>
<td>West Fiji ($p=0.0015$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.1046$), East Fiji ($p=0.1777$)</td>
<td>Early Tonga ($p=0.1046$), East Fiji ($p=0.7655$)</td>
<td></td>
<td>Early Tonga ($p=0.1777$), Late Tonga ($p=0.7655$)</td>
</tr>
<tr>
<td>Dentate Area $\alpha$=0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0174$)</td>
<td>West Fiji ($p=0.0226$)</td>
<td>Early Tonga ($p=0.0174$), Late Tonga ($p=0.0226$), East Fiji ($p=0.0008$)</td>
<td>West Fiji ($p=0.0008$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.9557$), East Fiji ($p=0.1507$)</td>
<td>Early Tonga ($p=0.9557$), East Fiji ($p=0.1632$)</td>
<td></td>
<td>Early Tonga ($p=0.1507$), Late Tonga ($p=0.1632$)</td>
</tr>
<tr>
<td>Dentate surface area $\alpha$=0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0206$)</td>
<td>West Fiji ($p=0.0061$)</td>
<td>Early Tonga ($p=0.0206$), Late Tonga ($p=0.0061$), East Fiji ($p=0.0004$)</td>
<td>West Fiji ($p=0.0004$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.4615$), East Fiji ($p=0.0803$)</td>
<td>Early Tonga ($p=0.4615$), East Fiji ($p=0.2958$)</td>
<td></td>
<td>Early Tonga ($p=0.0803$), Late Tonga ($p=0.2958$)</td>
</tr>
</tbody>
</table>

Table 5.7. Post-hoc comparisons of attribute distribution between four Lapita samples from the Eastern Lapita Province. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical $p$ values. Statistical significance is determined at different $\alpha$ values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The $\alpha$ values were determined using the Benjamini-Hochberg method.
Figure 5.6. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

Figure 5.7. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.
Figure 5.8. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji and group 4 represents East Fiji.

For the nominal variables of symmetry, lime-filling, zone direction, and infilling of motifs, only infilling differs significantly between groups (Table 5.8). Post-hoc tests of motif infilling indicate that West Fiji differs from all samples and Early Tonga also differs from Late Tonga (Table 5.9).

<table>
<thead>
<tr>
<th>Categorical Attributes</th>
<th>Lime filling</th>
<th>Symmetry</th>
<th>Direction of vessel zone</th>
<th>Motif infilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>*p value</td>
<td>0.232</td>
<td>0.130</td>
<td>0.396</td>
<td>*0.000</td>
</tr>
</tbody>
</table>

Table 5.8. P values derived from Fischer’s Exact test to determine the significance of association between attributes and ceramic sherds from the four sample groups. Asterisk indicates statistical significance at $\alpha = 0.05$.  


Table 5.9. Post-hoc comparisons of motif infilling between four Lapita samples from the Eastern Lapita Province as determined through individual Fischer’s Exact tests. The \( \alpha \) value was determined using the Benjamini-Hochberg method.

For the analysis of elements, motifs, and processes, both the number per sherd and frequency were compared between groups. For the number of elements, motifs, and processes per sherd, the distribution of the attributes was first assessed through observation of resulting histograms. The number of motifs per sherd was not normally distributed, but the residuals were; all other attributes were normally distributed. The relationship between attributes and dentate density, sherd length, and sherd width was then assessed through a bivariate linear fit regression model. Results indicate that density, sherd width, and sherd length are significant predictors for the number of elements and motifs per sherd and are therefore controlled for during ANCOVA (Table 5.10). Sherd length is a significant predictor of the number of processes per sherd and is controlled for in ANCOVA (Table 5.10).

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Dentate density</th>
<th>Sherd width</th>
<th>Sherd length</th>
</tr>
</thead>
<tbody>
<tr>
<td># Elements/Sherd</td>
<td>*0.002</td>
<td>*0.0289</td>
<td>*0.0069</td>
</tr>
<tr>
<td># Motifs/Sherd</td>
<td>*0.0035</td>
<td>*0.0001</td>
<td>*0.0001</td>
</tr>
<tr>
<td># Processes/Sherd</td>
<td>0.1540</td>
<td>0.0837</td>
<td>*0.0203</td>
</tr>
</tbody>
</table>

Table 5.10. P values derived from bivariate linear fit regression between dentate density, sherd length, sherd width, and the number of elements, motifs, and processes per sherd for the Eastern Lapita region. Significance is denoted by asterisk. Significance indicates that dentate density, sherd width, and/or sherd length are significant predictors of attributes and must be controlled for in subsequent analysis.

ANCOVA indicates that the number of elements \( (p=0.0002) \) and motifs \( (p=0.0002) \) differ significantly between groups, while the number of processes
per sherd do not. However, post-hoc tests reveal that none of the comparisons between samples differ for the number of elements and motifs per sherd.

Using Fischer’s Exact test, the frequency of elements ($p=0.008$) and motifs ($p=0.002$) vary between groups, but process frequency does not ($p=0.190$). Individual Fischer’s Exact tests between each group pair indicate which samples differ (Table 5.11). For element frequency, West Fiji differs from each group; no other comparisons differ (Fig. 5.9). For motif frequency, West Fiji differs from Early Tonga and East Fiji, and Early Tonga differs from East Fiji (Fig. 5.10). However, given that element, motif frequency, and process frequency are calculated by recording more than one observation per sherd, the assumption of independence is violated for Fischer’s Exact test. Results; therefore, must be interpreted with caution. For this reason, contingency tables are provided for comparing sample groups (Tables 5.12, 5.13, 5.14).

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element frequency</strong>&lt;br&gt;α=0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.008$)</td>
<td>West Fiji ($p=0.012$)</td>
<td>Early Tonga ($p=0.008$), Late Tonga ($p=0.012$), East Fiji ($p=0.011$)</td>
<td>West Fiji ($p=0.011$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.820$), East Fiji ($p=0.355$)</td>
<td>Early Tonga ($p=0.820$), East Fiji ($p=0.379$)</td>
<td>Early Tonga ($p=0.355$), Late Tonga ($p=0.379$)</td>
<td></td>
</tr>
<tr>
<td><strong>Motif frequency</strong>&lt;br&gt;α=0.025</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.011$), East Fiji ($p=0.010$)</td>
<td>Early Tonga ($p=0.011$), East Fiji ($p=0.000$)</td>
<td>West Fiji ($p=0.000$), Early Tonga ($p=0.010$)</td>
<td></td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.749$)</td>
<td>Early Tonga ($p=0.749$), West Fiji ($p=0.132$), East Fiji ($p=0.390$)</td>
<td>Late Tonga ($p=0.132$)</td>
<td>Late Tonga ($p=0.390$)</td>
</tr>
</tbody>
</table>

Table 5.11. Post-hoc comparisons of element and motif frequency values resulting from individual Fischer’s Exact tests between sample groups in the Eastern Lapita Province. The α value was determined using the Benjamini-Hochberg method.
Figure 5.9. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, and sample 4 represents East Fiji.
Figure 5.10. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, and sample 4 represents East Fiji.
<table>
<thead>
<tr>
<th>Count</th>
<th>Total %</th>
<th>Sample group</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>19</td>
<td>5.71</td>
<td>18</td>
<td>5.41</td>
<td>18</td>
<td>5.41</td>
<td>18</td>
<td>5.41</td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>2.70</td>
<td>9</td>
<td>2.70</td>
</tr>
<tr>
<td>1.3</td>
<td>11</td>
<td>3.30</td>
<td>4</td>
<td>1.20</td>
<td>9</td>
<td>2.70</td>
<td>11</td>
<td>3.30</td>
</tr>
<tr>
<td>1.4</td>
<td>12</td>
<td>3.60</td>
<td>7</td>
<td>2.10</td>
<td>15</td>
<td>4.50</td>
<td>10</td>
<td>3.00</td>
</tr>
<tr>
<td>1.5</td>
<td>2</td>
<td>0.60</td>
<td>5</td>
<td>1.50</td>
<td>8</td>
<td>2.40</td>
<td>4</td>
<td>1.20</td>
</tr>
<tr>
<td>1.6</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
<td>3</td>
<td>0.90</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
<td>5</td>
<td>1.50</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>2.2</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
</tr>
<tr>
<td>21.1</td>
<td>5</td>
<td>1.50</td>
<td>3</td>
<td>0.90</td>
<td>1</td>
<td>0.30</td>
<td>3</td>
<td>0.90</td>
</tr>
<tr>
<td>21.11</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.30</td>
</tr>
<tr>
<td>22.1</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>9</td>
<td>2.70</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>6.1</td>
<td>2</td>
<td>0.60</td>
<td>2</td>
<td>0.60</td>
<td>7</td>
<td>2.10</td>
<td>8</td>
<td>2.40</td>
</tr>
<tr>
<td>6.2</td>
<td>2</td>
<td>0.60</td>
<td>2</td>
<td>0.60</td>
<td>9</td>
<td>2.70</td>
<td>11</td>
<td>3.30</td>
</tr>
<tr>
<td>6.3</td>
<td>8</td>
<td>2.40</td>
<td>8</td>
<td>2.40</td>
<td>4</td>
<td>1.20</td>
<td>12</td>
<td>3.60</td>
</tr>
<tr>
<td>6.4</td>
<td>4</td>
<td>1.20</td>
<td>5</td>
<td>1.50</td>
<td>2</td>
<td>0.60</td>
<td>5</td>
<td>1.50</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0.30</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>22.82</td>
<td>62</td>
<td>18.62</td>
<td>99</td>
<td>29.73</td>
<td>96</td>
<td>28.83</td>
</tr>
</tbody>
</table>

Table 5.12. Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. Element code refers to the updated Chiu and Sand (2005) system presented in Table 4.2.
<table>
<thead>
<tr>
<th>Motif</th>
<th>Count</th>
<th>Sample group</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(Anson)</td>
<td>0</td>
<td>0.00</td>
<td>1.59</td>
<td>0.00</td>
</tr>
<tr>
<td>A134</td>
<td>1</td>
<td>(Anson)</td>
<td>0.59</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>A283</td>
<td>0</td>
<td>(Anson)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td>0.00</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td></td>
<td>0.59</td>
<td>5.29</td>
<td>3.18</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.78</td>
<td>2.18</td>
<td>8.47</td>
<td>2.18</td>
</tr>
<tr>
<td>DE1</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>DE3</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DE8</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>DZC</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>2.18</td>
<td>0.00</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td></td>
<td>1.78</td>
<td>3.18</td>
<td>3.18</td>
<td>0.00</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td></td>
<td>1.18</td>
<td>2.18</td>
<td>2.18</td>
<td>1.00</td>
</tr>
<tr>
<td>GZ1</td>
<td>3</td>
<td>(Mead)</td>
<td>1.78</td>
<td>2.18</td>
<td>3.18</td>
<td>6.55</td>
</tr>
<tr>
<td>GZ2</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>H</td>
<td>3</td>
<td></td>
<td>1.78</td>
<td>2.18</td>
<td>2.18</td>
<td>2.00</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td></td>
<td>0.59</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>4.00</td>
</tr>
<tr>
<td>M</td>
<td>0</td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>M1</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M10</td>
<td>0</td>
<td>(Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Motif</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>Sample group</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>M16 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.59</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>M18 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>2.18</td>
<td>0.00</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>M19 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>3.18</td>
<td>0.00</td>
<td>3.18</td>
<td></td>
</tr>
<tr>
<td>M29 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>4.37</td>
<td>4.37</td>
<td></td>
</tr>
<tr>
<td>M3 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>M30 (Mead)</td>
<td>0.59</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>M35 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>M7 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.59</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>N1.1 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>2.18</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.59</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.00</td>
<td>0.00</td>
<td>2.18</td>
<td>0.00</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>RZ1 (Mead)</td>
<td>2.18</td>
<td>0.00</td>
<td>2.18</td>
<td>0.00</td>
<td>4.37</td>
<td></td>
</tr>
<tr>
<td>RZ3 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>5.96</td>
<td>0.00</td>
<td>5.96</td>
<td></td>
</tr>
<tr>
<td>TB3.3 (Mead)</td>
<td>0.00</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>23.08</td>
<td>31</td>
<td>18.34</td>
<td>169</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.13. Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system.
Table 5.14. Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. Process code used is that outlined in Sharp (1988).

<table>
<thead>
<tr>
<th>Process</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS</td>
<td>5 (2.53%)</td>
<td>2 (1.01%)</td>
<td>3 (1.52%)</td>
<td>7 (3.54%)</td>
</tr>
<tr>
<td>DECR</td>
<td>0 (0.00%)</td>
<td>0 (0.00%)</td>
<td>1 (0.51%)</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>HDM</td>
<td>0 (0.00%)</td>
<td>1 (0.51%)</td>
<td>1 (0.51%)</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>INT</td>
<td>18 (9.09%)</td>
<td>21 (10.61%)</td>
<td>24 (12.12%)</td>
<td>19 (9.60%)</td>
</tr>
<tr>
<td>MR</td>
<td>4 (2.02%)</td>
<td>2 (1.01%)</td>
<td>0 (0.00%)</td>
<td>6 (3.03%)</td>
</tr>
<tr>
<td>RP</td>
<td>25 (12.63%)</td>
<td>22 (11.11%)</td>
<td>20 (10.10%)</td>
<td>17 (8.59%)</td>
</tr>
<tr>
<td></td>
<td>52 (26.26%)</td>
<td>48 (24.24%)</td>
<td>49 (24.75%)</td>
<td>49 (24.75%)</td>
</tr>
</tbody>
</table>

5.3. Discussion

It is clear from the above results that the boundaries of the Eastern Lapita Province no longer appear as a cohesive unit. Results indicate that West Fiji, East Fiji, Early Tonga and Late Tonga differ in the distribution of elements/motifs and structural attributes of design. Discrepancy exists between categorical and quantitative variables of ceramic design, which may be due to the limited size of ceramic sherds used for analysis, or may suggest difference in the way design is selected and subsequently applied to a vessel surface. Regardless of the reason, this case study suggests that the Eastern Lapita Province does not represent a homogenous region, as far as ceramic design is concerned. The null hypothesis for Case Study 1:

*West Fiji, East Fiji, and Tonga do not differ in the distribution of elements/motifs or structural attributes of ceramic design during the Lapita period*
is rejected. West Fiji, East Fiji, Early and Late Tonga do differ in the distribution of elements/motifs and structural attributes of ceramic design during the Lapita period. Difference exists not only between groups, but between ceramic attributes.

Categorical variables of symmetry, lime-filling, and zone direction show a pattern of no difference between the four groups, aside from infilling of motifs. This suggests that motif infilling appears early in both West Fijian and Tonga settlement, but then decreases. Samples with the largest to smallest amount of infilling are ordered as such: West Fiji, Early Tonga, East Fiji, Late Tonga. While this could potentially signal interaction between West Fiji and Early Tonga, it is also just as likely that it represents common ancestry. The fact that East Fiji and Late Tonga differ significantly from West Fiji either indicates that infilling motifs had fallen out of practice by the time both were settled or that potters from Late Tonga interacted with potters in East Fiji. To differentiate between these explanations requires multiple lines of evidence, including the analysis of element/motif frequency and quantitative structural design characters.

Several trends can be discerned from the analysis of quantitative structural attributes. First are the results that dentate density is a significant predictor of Leica and LEXT attributes. Dentate density, sherd length, and sherd width are also significant predictors of the number of elements and motifs per shed. This has important implications for Lapita design analysis. If these variables play a role in predicting the size and shape of dentate stamping, along with the frequency of elements and motifs per sherd, then Lapita archaeologists must incorporate these variables in any comparison of element/motif and structural attributes within and between Lapita regions.

All Leica attributes differ significantly between groups. The general trend is that Late Tonga and East Fiji do not differ, whereas, West Fiji differs from most groups. Dentate design is more densely applied on samples from West Fiji than on sherds from East Fiji, Early Tonga, and Late Tonga; the latter groups show no statistical difference for this attribute distribution. For spacing 2, no groups differ, which is likely due to the fact that density is controlled for. Overall, the size and layout of dentate stamping is most similar between East Fiji and Tonga, to the exclusion of West Fiji.
For LEXT attributes, only dentate length, area, and surface area differ significantly between groups in post-hoc comparisons. For these attributes, West Fiji differs from all groups, whereas all other comparisons do not differ. Overall, LEXT attributes indicate that West Fiji differs from East Fiji, Late Tonga, and Early Tonga for dentate length, width, surface area, and area, but all groups share similar measurements for dentate depth and volume.

Results of element/motif analysis are more difficult to evaluate given that dentate density, sherd width, and sherd length are significant predictors of the number of elements and motifs per sherd. However, this may change depending on sample size. While analysis of entire pots would be ideal, such assemblages rarely exist in Lapita sites, especially those from the Eastern Lapita Province. Results derived from comparisons of elements and motifs must be interpreted with caution. Preliminary results do not suggest a clear pattern, in contrast with structural results. Post-hoc comparisons indicate that for the number of elements and motif per sherd, no regions differ. Post-hoc comparisons for element frequency indicates that West Fiji differs from all groups. For motif frequency, West Fiji differs from Early Tonga and East Fiji, but not Late Tonga, and Early Tonga differs from East Fiji. These results suggest that East Fiji is most similar to Late Tonga for motif frequency and to both Early and Late Tonga for element frequency. Despite the results, frequency tables suggest lack of any noticeable difference between groups based on the number of shared element/motif types and element/motif diversity. West Fiji, however, does have the greatest diversity of element and motif type. Based on element/motif frequency table comparisons alone, the Eastern Lapita region appears cohesive, while comparison of structural variation would suggest otherwise.

Taken together, the above results suggest that for East Fiji, the structural application of dentate stamped tools is most similar to Early and Late Tonga as opposed to West Fiji. More specifically, East Fiji is more similar to Late Tonga than Early Tonga, although it only differs from Early Tonga for three attributes. This may suggest that East Fiji was settled from Late Tonga or that both regions interacted to some degree. Comparison of Early and Late Tonga suggests that the size of the tools used for design application does not differ through time, but the density of design application does differ. Although West Fiji appears to stand apart from its eastern Lapita counterparts, this
region does share some structural attributes with Early and Late Tonga, suggesting either interaction and/or common ancestry. In order to distinguish between the two, it would be necessary to determine which attributes postdate initial settlement and are unique to each region. These innovative attributes would then be compared. Overall, Case Study 1 questions the cohesiveness of the Eastern Lapita Province, suggesting that structural attributes require further testing to confirm/disprove the results provided here.
Chapter 6.

Case Study 2 - A View from the West: Comparison of Lapita Design Beyond the Eastern Lapita Province

The purpose of the second case study is to expand the structural approach beyond the Eastern Lapita Province by including sites from both the Western and Southern Lapita Provinces. The same attributes will be applied and analyzed to determine if these designations hold true. The Eastern Lapita Province is organized into West Fiji, East Fiji, Early Tonga, and Late Tonga as in the previous case study. If differences within the Eastern Lapita Province are less than differences between groups to the south and west, then this will suggest support for the province model. If samples from within the Eastern Lapita Province align more with samples from the Southern and Western Province, then the province categorization will be questioned. If this occurs, the next step is to determine if attribute type plays a role, more specifically, if structural attributes provide a pattern that is inconsistent with element/motif attributes. Below I outline the methods used to select archaeological samples, along with results from statistical analysis and a discussion of results.

6.1. Methods

As indicated in Chapter 4, 17 quantitative and qualitative attributes were recorded for each sample within the Eastern Lapita Province, along with the southern and western Lapita samples. Archaeological sites from within the Eastern Lapita Province samples are the same as in Case Study 1. Archaeological sites used for the southern and western Lapita samples will be discussed, followed by a brief outline of attribute analysis.
6.1.1. Archaeological Samples

In order to demonstrate the utility of the new approach outside of the Eastern Lapita Province and to determine if design within this province is distinct from others, samples from the Western and Southern Lapita Provinces, as they are currently defined, were sought. The Western Lapita province represents the region east of Ambitle, Talasea, and Eloaue and extends as far east as Vanuatu (Spriggs 1997). This province is distinguished from the Far Western Lapita Province by less elaborate decoration and a decrease in vessel forms (Spriggs 1997). Given the proximity of Vanuatu to Fiji, it was decided that a sample from this region be used to test for distinction between the Western and Eastern Lapita Provinces. The Southern Lapita Province is represented by Lapita sites found throughout New Caledonia (Sand 2000). This is differentiated from other provinces by the presence of stylized dentate-stamped faces on carinated pots and flat-bottomed bowls (Sand 2000:26). Twenty-five sherds were sought from each region in order to standardize sample size and enable comparison to the Eastern Lapita sample group. To be selected, each sherd was required to have at least four lines of clearly visible dentate stamped impressions.

Given the lack of Western Lapita sherds available for analysis at Simon Fraser University, a sample was graciously loaned from the Vanuatu Cultural Centre by Dr. Stuart Bedford. All 25 ceramics sherds come from the site of Teouma, which is located on the south coast of Efate in central Vanuatu. Teouma is currently considered the oldest Lapita site in Vanuatu, dating to as early as 3000 BP, with occupation likely occurring by 2940-2870 cal BP and ending around 2870-2750 cal BP (Bedford et al. 2006; Petchey et al. 2015). This date range is based on tephra dates underlying the initial Lapita deposit and reliable dating of later Lapita occupations further south ofEfate (Bedford et al. 2006), along with a recent Bayesian chronometric hygiene approach applied to appropriate radiocarbon data (Petchey et al. 2015). These dates indicate that Teouma was occupied during the same time as initial landfall in Tonga (2850-2830 cal BP) and West Fiji (3020-2860 cal BP) (Petchey et al. 2015). The site was initially used as a cemetery and contains the largest representation of Lapita ceramics in direct association with burial practices (Bedford et al. 2006). Sherds in this sample derive from either the cemetery zone at the site or the adjacent midden zone to the east (Bedford
Sherds from this site closely resemble sherds from other sites within the Western Lapita Province (Bedford 2006; Bedford et al. 2009). This, along with the close geographic and temporal proximity to Fiji, in comparison to other sites within the Western Lapita region, makes Teouma an ideal assemblage to compare to samples from the Eastern Lapita Province. Sherds were selected as a grab sample from excavations that took place between 2004 to 2010 (Bedford 2006; Bedford et al. 2009). From the 25 sherds used for analysis with the Leica, ten were selected for analysis with the LEXT, based on shape and size suitability.

To supplement the Western Lapita sample, while at the same time extending the range for comparison with the Eastern samples, a sample from the current Southern Lapita Province was sought. Again, due to the lack of Southern Lapita sherds available for analysis at Simon Fraser University, a sample was graciously loaned from the Institut d’archéologie de la Nouvelle-Calédonie et du Pacifique by Dr. Christophe Sand. Twenty-five sherds were chosen as a grab sample from Site WKO013A, the type site for Lapita in the region. This site is located in the northwest region of Grand Terre, and represents a large hamlet-sized permanent settlement (Sand 2001, 2010). Dates for this site are the earliest in the Province, as early as 3000 BP to as late as 2750 BP (Sand et al. 2011). However, Petchey et al. (2015) note that these dates have not yet been securely dated through a Bayesian chronometric hygiene approach. Nevertheless, the dates for Lapita are well within the range of initial occupation for West Fiji, East Fiji, and Tonga. Sherds from the Lapita site (WKO013A) were selected from the 1995 excavation assemblage (Sand 1995). From the 25 sherds used for analysis with the Leica, ten were selected for analysis with the LEXT, based on shape and size suitability.

6.1.2. Attribute Analysis

Once selected, ceramic samples were analyzed for both structural and element/motif attributes. Attributes were divided into nominal and continuous categories. Nominal variables consist of zone direction, process type, presence/absence of motif infilling, lime, and slip, along with symmetry pattern and element/motif recording. Continuous attributes consist of dentate length, width, area, surface area, depth, volume, spacing (1 and 2), density, and the number of elements/motifs/processes per sherd.
Dentate length, width, density, and spacing measurements were recorded using the Leica. Dentate length and width was also measured using the LEXT, along with dentate area, surface area, depth, and volume. Attribute descriptions are found in Chapter 4 (Table 4.1). Once recorded, attributes were compared between samples in order to determine similarity/dissimilarity in distribution. Statistical methodology is outlined in Chapter 4 (section 4.2.2). Results of statistical analysis are presented below.

6.2. Results

Before comparing continuous attribute distribution between groups, the relationship between attributes and dentate density, sherd length, and sherd width was first assessed through bivariate linear fit regression models. Results indicate that for Leica attributes, density is a significant predictor of dentate width, length, spacing 1 and spacing 2 (Table 6.1). Density is therefore modeled as a covariate for Leica attributes. For LEXT attributes, the predictive significance of potential covariates differs for each attribute (Table 6.1). For dentate length, depth, area, and volume, density is a significant predictor and is therefore controlled for as a covariate. For dentate surface area, none of the potential covariates have predictive significance, and for dentate width, sherd length and sherd width are significant predictors and are controlled for as covariates.

Histograms for attribute distributions were viewed to access data normality. For Leica attributes, dentate density and dentate spacing 2 required a natural log transformation, all other histograms are normally distributed. For LEXT attributes, dentate density, dentate width, surface area, and volume required a natural log transformation, all other histograms are normally distributed.

Before running the ANCOVA model for Leica attributes, the distribution of density between groups was first assessed. Results from ANOVA indicate that dentate density differs significantly between groups (p=0.0001). Post-hoc tests indicate that the only samples that do not differ are Early Tonga and East Fiji, Late Tonga and East Fiji, New Caledonia and Early Tonga, and Vanuatu and West Fiji (Table 6.2) (Fig. 6.1).
### Leica MZ6 attributes

<table>
<thead>
<tr>
<th>Dentate density</th>
<th>Sherd Length</th>
<th>Sherd Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate length</td>
<td>0.001</td>
<td>0.4991</td>
</tr>
<tr>
<td>Dentate width</td>
<td>0.001</td>
<td>0.6346</td>
</tr>
<tr>
<td>Dentate spacing 1</td>
<td>0.002</td>
<td>0.6532</td>
</tr>
<tr>
<td>Dentate spacing 2</td>
<td>0.001</td>
<td>0.3553</td>
</tr>
</tbody>
</table>

### LEXT 4000 attributes

| Dentate width | 0.8048 | *0.0245 | *0.0015 |
| Dentate length | 0.0001  | 0.7913  | 0.7519  |
| Dentate depth  | *0.0345 | 0.1599  | 0.1816  |
| Dentate area   | *0.0028 | 0.5102  | 0.6960  |
| Dentate surface area | 0.2767 | 0.3365  | 0.9426  |
| Dentate volume | *0.0005 | 0.9825  | 0.5939  |

Table 6.1. P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 and LEXT 4000 attributes for the Eastern, Southern, and Western Lapita sample groups. Significance is denoted by asterisk. Significance indicates that the covariate is a significant predictor of dentate attributes and must be controlled for in subsequent analysis.

### Table 6.2.

<table>
<thead>
<tr>
<th>Dentate density</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td>a=0.037</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji (p=0.0001), Late Tonga (p=0.0040), Vanuatu (p=0.0001)</td>
<td>Early Tonga (p=0.0040), West Fiji (p=0.0001), New Caledonia (p=0.0001), Vanuatu (p=0.0001)</td>
<td>Early Tonga (p=0.0001), New Caledonia (p=0.0012), West Fiji (p=0.0078), Late Tonga (p=0.0001), Vanuatu (p=0.0001)</td>
<td>East Fiji (p=0.0012), West Fiji (p=0.0078), Late Tonga (p=0.0001), Vanuatu (p=0.0001)</td>
<td>East Fiji (p=0.0012), Late Tonga (p=0.0001), East Fiji (p=0.0001), New Caledonia (p=0.0001)</td>
<td>East Tonga (p=0.0903), West Fiji (p=0.1129)</td>
</tr>
</tbody>
</table>

| Not significantly different from: | New Caledonia (p=0.0903), East Fiji (p=0.1129) | East Fiji (p=0.1858) | Vanuatu (p=0.0422) | Early Tonga (p=0.1129), Late Tonga (p=0.1858) | Early Tonga (p=0.0903) | West Fiji (p=0.0422) |

Table 6.2. Post-hoc comparisons of density attribute distribution between Lapita samples from the Eastern, Western, and Southern Provinces. Chart indicates which groups differ significantly by indication of statistical p values. Statistical significance is determined at an α level calculated using the Benjamini-Hochberg method.
Figure 6.1. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

ANCOVA indicates that the distribution of all Leica MZ6 attributes differ significantly between groups, while controlling for dentate density (Table 6.3). Post-hoc tests indicate where differences lie (Table 6.4). For dentate length, Early Tonga, Late Tonga and East Fiji differ from all groups, but East Fiji and Late Tonga do not differ from each other; all other sample comparisons differ significantly (Fig. 6.2). For dentate width, Late Tonga and East Fiji differ from all groups, except from each other; all other sample comparisons do not differ significantly (Fig. 6.3). For spacing 1, the only significant difference between groups is for West Fiji and East Fiji, East Fiji and New Caledonia, and East Fiji and Vanuatu; all other sample comparisons are not significantly different (Fig. 6.4). For spacing 2, there are no significant differences between groups. The F ratio obtained from each attribute comparison is above 1, indicating that there is more difference between than within groups (Table 6.3).

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Dentate length</th>
<th>Dentate width</th>
<th>Dentate Spacing 1</th>
<th>Spacing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>p value</td>
<td>*0.0001</td>
<td>*0.0001</td>
<td>*0.0001</td>
<td>*0.0001</td>
</tr>
<tr>
<td>F-ratio</td>
<td>22.9848</td>
<td>8.2675</td>
<td>5.6202</td>
<td>9.0727</td>
</tr>
</tbody>
</table>

Table 6.3. P values derived from comparisons of means between the Eastern, Southern, and Western Lapita sample groups using ANCOVA. Asterisk indicates statistical significance at α=0.05.
<table>
<thead>
<tr>
<th><strong>Leica MZ6 attributes</strong></th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dentate length</strong></td>
<td>Late Tonga ($p=0.0064$), West Fiji ($p=0.0047$), East Fiji ($p=0.0001$), New Caledonia ($p=0.0109$), Vanuatu ($p=0.0058$)</td>
<td>Early Tonga ($p=0.0064$), West Fiji ($p=0.0001$), New Caledonia ($p=0.0001$), Vanuatu ($p=0.0001$)</td>
<td>Early Tonga ($p=0.0047$), Late Tonga ($p=0.0001$), East Fiji ($p=0.0001$)</td>
<td>Early Tonga ($p=0.0001$), Late Tonga ($p=0.0001$), New Caledonia ($p=0.0001$), Vanuatu ($p=0.0001$)</td>
<td>Early Tonga ($p=0.0109$), Late Tonga ($p=0.0001$), East Fiji ($p=0.0001$)</td>
<td>Early Tonga ($p=0.0058$), Late Tonga ($p=0.0001$), East Fiji ($p=0.0001$)</td>
</tr>
<tr>
<td><strong>Not significantly different from:</strong></td>
<td>East Fiji ($p=0.1801$)</td>
<td>New Caledonia ($p=0.6602$), Vanuatu ($p=0.9033$)</td>
<td>Late Tonga ($p=0.1801$)</td>
<td>West Fiji ($p=0.6602$), Vanuatu ($p=0.5937$)</td>
<td>West Fiji ($p=0.9033$), New Caledonia ($p=0.5937$)</td>
<td></td>
</tr>
<tr>
<td><strong>Dentate width</strong></td>
<td>Late Tonga ($p=0.0003$), East Fiji ($p=0.0081$)</td>
<td>Early Tonga ($p=0.0003$), West Fiji ($p=0.0001$), New Caledonia ($p=0.0002$), Vanuatu ($p=0.0008$)</td>
<td>Late Tonga ($p=0.0001$), East Fiji ($p=0.0007$)</td>
<td>Early Tonga ($p=0.0001$), Late Tonga ($p=0.0007$), New Caledonia ($p=0.0037$), Vanuatu ($p=0.0080$)</td>
<td>Late Tonga ($p=0.0002$), East Fiji ($p=0.0037$)</td>
<td>Late Tonga ($p=0.0008$), East Fiji ($p=0.0080$)</td>
</tr>
<tr>
<td><strong>Not significantly different from:</strong></td>
<td>West Fiji ($p=0.2693$), New Caledonia ($p=0.7292$), Vanuatu ($p=0.6399$)</td>
<td>East Fiji ($p=0.2751$)</td>
<td>Early Tonga ($p=0.2693$), New Caledonia ($p=0.4189$), Vanuatu ($p=0.5235$)</td>
<td>Late Tonga ($p=0.2751$)</td>
<td>Early Tonga ($p=0.7292$), West Fiji ($p=0.4189$), Vanuatu ($p=0.8658$)</td>
<td>Early Tonga ($p=0.6399$), West Fiji ($p=0.5235$), Vanuatu ($p=0.8658$)</td>
</tr>
<tr>
<td><strong>Dentate spacing 1</strong></td>
<td>East Fiji ($p=0.0004$)</td>
<td>West Fiji ($p=0.0004$), New Caledonia ($p=0.0015$), Vanuatu ($p=0.0002$)</td>
<td>East Fiji ($p=0.0015$)</td>
<td>East Fiji ($p=0.0002$)</td>
<td>East Fiji ($p=0.0002$)</td>
<td></td>
</tr>
<tr>
<td><strong>Significantly different from:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga (p=0.3769), West Fiji (p=0.1084), East Fiji (p=0.0207), New Caledonia (p=0.3271), Vanuatu (p=0.0562)</td>
<td>Early Tonga (p=0.3769), West Fiji (p=0.0262), East Fiji (p=0.1524), New Caledonia (p=0.0776), Vanuatu (p=0.0159)</td>
<td>Early Tonga (p=0.1084), Late Tonga (p=0.0262), New Caledonia (p=0.4789), Vanuatu (p=0.6474)</td>
<td>Early Tonga (p=0.0207), Late Tonga (p=0.1524)</td>
<td>Early Tonga (p=0.3271), Late Tonga (p=0.0776), West Fiji (p=0.4789), Vanuatu (p=0.2693)</td>
<td>Early Tonga (p=0.0562), Late Tonga (p=0.0159), West Fiji (p=0.6474), New Caledonia (p=0.2693)</td>
</tr>
<tr>
<td>Dentate spacing 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*α*: none of the comparisons are significant

**Table 6.4.** Post-hoc comparisons of attribute distribution between Lapita samples in the Eastern, Western, and Southern Provinces. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical p values. Statistical significance is determined at different α values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The α values were determined using the Benjamini-Hochberg method.

**Figure 6.2.** Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.
Figure 6.3. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

Figure 6.4. Least squares means plot for dentate spacing 1 values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

The distribution of all LEXT 4000 attributes indicates that dentate width does not differ significantly between samples, all other attributes differ significantly, as determined through ANCOVA (Table 6.5). Post-hoc tests indicate where differences lie (Table 6.6). For dentate volume and depth, none of the sample comparisons are significantly
different. For dentate length, Early Tonga differs from West Fiji and Vanuatu, Late Tonga differs from West Fiji, New Caledonia and Vanuatu, and East Fiji differs from West Fiji, New Caledonia, and Vanuatu (Fig. 6.5). For dentate area, West Fiji differs from each group, East Fiji differs from New Caledonia and Vanuatu, and New Caledonia and Vanuatu differ from each other; no other sample comparisons differ significantly (Fig. 6.6). For dentate surface area, West Fiji and Vanuatu differ from all groups and New Caledonia and East Fiji also differ; no other sample comparisons differ significantly (Fig. 6.7).

<table>
<thead>
<tr>
<th>LEXT attributes</th>
<th>Dentate width</th>
<th>Dentate length</th>
<th>Dentate depth</th>
<th>Dentate area</th>
<th>Dentate surface area</th>
<th>Dentate volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>p value</td>
<td>0.0520</td>
<td>*0.0001</td>
<td>*0.0220</td>
<td>*0.0002</td>
<td>*0.0001</td>
<td>*0.0149</td>
</tr>
<tr>
<td>F-ratio</td>
<td>2.1713</td>
<td>11.0097</td>
<td>2.7274</td>
<td>5.4217</td>
<td>25.8678</td>
<td>2.9412</td>
</tr>
</tbody>
</table>

Table 6.5. P values derived from comparisons of means between the Eastern, Southern, and Western Lapita sample groups using ANCOVA. Asterisk indicates statistical significance at α=0.05.
<table>
<thead>
<tr>
<th>LEXT attributes</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha=0.027$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0051$), Vanuatu ($p=0.0063$)</td>
<td>West Fiji ($p=0.0001$), New Caledonia ($p=0.0013$), Vanuatu ($p=0.0002$)</td>
<td>Early Tonga ($p=0.0051$), Late Tonga ($p=0.0001$), East Fiji ($p=0.0001$)</td>
<td>West Fiji ($p=0.0001$), New Caledonia ($p=0.0025$), Vanuatu ($p=0.0002$)</td>
<td>Late Tonga ($p=0.0013$), East Fiji ($p=0.0025$)</td>
<td>Early Tonga ($p=0.0063$), Late Tonga ($p=0.0002$), East Fiji ($p=0.0002$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.0721$), East Fiji ($p=0.1210$), New Caledonia ($p=0.0063$)</td>
<td>Early Tonga ($p=0.0721$), East Fiji ($p=0.7766$)</td>
<td>New Caledonia ($p=0.1680$), Vanuatu ($p=0.8339$)</td>
<td>Early Tonga ($p=0.1210$), Late Tonga ($p=0.7766$)</td>
<td>Early Tonga ($p=0.0663$), West Fiji ($p=0.1680$), Vanuatu ($p=0.1457$)</td>
<td>West Fiji ($p=0.8339$), New Caledonia ($p=0.1457$)</td>
</tr>
<tr>
<td>Dentate area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha=0.017$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0051$)</td>
<td>West Fiji ($p=0.0089$)</td>
<td>Early Tonga ($p=0.0051$), Late Tonga ($p=0.0089$), East Fiji ($p=0.0001$), New Caledonia ($p=0.0164$), Vanuatu ($p=0.0001$)</td>
<td>West Fiji ($p=0.0001$), New Caledonia ($p=0.0103$), Vanuatu ($p=0.0001$)</td>
<td>West Fiji ($p=0.0164$), East Fiji ($p=0.0103$), New Caledonia ($p=0.0001$)</td>
<td>West Fiji ($p=0.0001$), East Fiji ($p=0.0001$), New Caledonia ($p=0.0001$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.9970$), East Fiji ($p=0.0991$), New Caledonia ($p=0.3008$), Vanuatu ($p=0.0701$)</td>
<td>Early Tonga ($p=0.9970$), East Fiji ($p=0.0988$), New Caledonia ($p=0.3149$), Vanuatu ($p=0.0981$)</td>
<td>Early Tonga ($p=0.0991$), Late Tonga ($p=0.0988$)</td>
<td>Early Tonga ($p=0.3008$), Late Tonga ($p=0.3149$)</td>
<td>Early Tonga ($p=0.0701$), Late Tonga ($p=0.0981$)</td>
<td></td>
</tr>
<tr>
<td>LEXT attributes</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>New Caledonia</td>
<td>Vanuatu</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Surface area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha=0.033$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.0002$), Vanuatu ($p=0.0001$)</td>
<td>West Fiji ($p=0.0002$), Vanuatu ($p=0.0001$)</td>
<td>Early Tonga ($p=0.0029$), Late Tonga ($p=0.0002$), East Fiji ($p=0.0001$), New Caledonia ($p=0.0164$), Vanuatu ($p=0.0001$)</td>
<td>West Fiji ($p=0.0001$), East Fiji ($p=0.0103$), Vanuatu ($p=0.0001$)</td>
<td></td>
<td>Early Tonga ($p=0.0001$), Late Tonga ($p=0.0001$), West Fiji ($p=0.0001$), East Fiji ($p=0.0001$), New Caledonia ($p=0.0001$)</td>
</tr>
</tbody>
</table>

| Not significantly different from: | Late Tonga ($p=0.3642$), East Fiji ($p=0.0487$), New Caledonia ($p=0.5245$) | Early Tonga ($p=0.3642$), East Fiji ($p=0.2754$), New Caledonia ($p=0.1256$) | Early Tonga ($p=0.0487$), Late Tonga ($p=0.2754$) | Early Tonga ($p=0.5245$), Late Tonga ($p=0.1256$) |  |  |

| Dentate depth $\alpha$=no comparisons are statistically significant |  |  |  |  |  |  |
| Dentate volume $\alpha$=no comparisons are statistically significant |  |  |  |  |  |  |

Table 6.6. Post-hoc comparisons of attribute distribution between Lapita samples from the Eastern, Western, and Southern Provinces. Chart indicates which attributes do and do not differ significantly between groups by indication of statistical $p$ values. Statistical significance is determined at different $\alpha$ values depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The $\alpha$ values were determined using the Benjamini-Hochberg method.
Figure 6.5. Least squares means plot for dentate length values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

Figure 6.6. Least squares means plot for dentate area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.
Figure 6.7. Least squares means plot for dentate surface area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Early Tonga, group 2 represents Late Tonga, group 3 represents West Fiji, group 4 represents East Fiji, group 5 represents New Caledonia and group 6 represents Vanuatu.

For the nominal variables of symmetry, lime-filling, zone direction, and in-filling of motifs, only lime-filling does not differ between groups; all other attributes differ significantly as indicated through Fischer’s Exact test (Table 6.7). Post-hoc tests indicate where differences lie (Table 6.8). For symmetry, New Caledonia differs from all groups, and East Fiji and Late Tonga both differ from Vanuatu; no other sample comparisons differ significantly. For zone direction, Vanuatu differs from each group; no other comparisons differ significantly. For motif infilling, Early Tonga differs from Late Tonga, West Fiji, and Vanuatu, Late Tonga differs from all groups except East Fiji, and East Fiji differs from West Fiji, New Caledonia and Vanuatu.

<table>
<thead>
<tr>
<th>Categorical Attributes</th>
<th>Lime filling</th>
<th>Symmetry</th>
<th>Direction of vessel zone</th>
<th>Motif infilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p ) value</td>
<td>0.411</td>
<td>*0.000</td>
<td>*0.000</td>
<td>*0.000</td>
</tr>
</tbody>
</table>

Table 6.7. \( p \) values derived from Fischer’s Exact test to determine the significance of association between attributes and ceramic sherds from the Eastern, Southern, and Western Lapita sample groups. Asterisk indicates statistical significance at \( \alpha = 0.05 \).
<table>
<thead>
<tr>
<th>Categorical attributes</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symmetry</strong> $\alpha=0.023$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>New Caledonia ($p=0.001$)</td>
<td>New Caledonia ($p=0.000$), Vanuatu ($p=0.001$)</td>
<td>New Caledonia ($p=0.001$)</td>
<td>New Caledonia ($p=0.000$), Vanuatu ($p=0.005$)</td>
<td>Early Tonga ($p=0.001$), Late Tonga ($p=0.000$), West Fiji ($p=0.001$), East Fiji ($p=0.000$), Vanuatu ($p=0.005$)</td>
<td>Late Tonga ($p=0.001$), East Fiji ($p=0.005$), New Caledonia ($p=0.005$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.070$), West Fiji ($p=0.748$), East Fiji ($p=0.142$), Vanuatu ($p=0.037$)</td>
<td>Early Tonga ($p=0.070$), West Fiji ($p=0.140$), East Fiji ($p=0.081$)</td>
<td>Early Tonga ($p=0.748$), Late Tonga ($p=0.140$), East Fiji ($p=0.676$), Vanuatu ($p=0.122$)</td>
<td>Early Tonga ($p=0.142$), Late Tonga ($p=0.081$), West Fiji ($p=0.676$)</td>
<td>Early Tonga ($p=0.037$), West Fiji ($p=0.122$)</td>
<td></td>
</tr>
<tr>
<td><strong>Zone direction</strong> $\alpha=0.017$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>Vanuatu ($p=0.000$)</td>
<td>Vanuatu ($p=0.000$)</td>
<td>Vanuatu ($p=0.000$), Vanuatu ($p=0.000$)</td>
<td>Vanuatu ($p=0.000$)</td>
<td>Early Tonga ($p=0.000$), Late Tonga ($p=0.000$), West Fiji ($p=0.000$), East Fiji ($p=0.000$), New Caledonia ($p=0.000$)</td>
<td></td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.132$), West Fiji ($p=0.438$), East Fiji ($p=0.722$), New Caledonia ($p=0.287$)</td>
<td>Early Tonga ($p=0.132$), West Fiji ($p=1.000$), East Fiji ($p=0.196$), New Caledonia ($p=0.039$)</td>
<td>Early Tonga ($p=0.438$), Late Tonga ($p=1.000$), East Fiji ($p=0.589$), New Caledonia ($p=0.082$)</td>
<td>Early Tonga ($p=0.722$), Late Tonga ($p=0.196$), West Fiji ($p=0.589$), New Caledonia ($p=0.913$)</td>
<td>Early Tonga ($p=0.287$), Late Tonga ($p=0.039$), West Fiji ($p=0.082$), East Fiji ($p=0.913$)</td>
<td></td>
</tr>
</tbody>
</table>
Table 6.8. Post-hoc comparisons of categorical attributes between Lapita samples from the Eastern, Western, and Southern Provinces. The $\alpha$ value was determined using the Benjamini-Hochberg method and is indicated after the attribute name.

For the analysis of elements, motifs, and processes, both the number per sherd and frequency were compared between groups. For the number of elements, motifs, and processes per sherd, the distribution of attributes was first assessed through observation of histograms. The number of motifs per sherd are not normally distributed, but the residuals are; all other attributes are normally distributed. Before comparing attribute distribution between groups through ANOVA, the relationship between attributes and dentate density, sherd width, and sherd length was determined through a bivariate linear fit regression model. Results indicate that density, sherd width, and sherd length are significant predictors of the number of elements/motifs/processes per sherd and are therefore controlled for during ANCOVA (Table 6.9). ANCOVA indicates that the number of elements ($p=0.0001$), motifs ($p=0.0001$), and processes ($p=0.0022$) per sherd differ significantly between groups. However, post-hoc tests with adjusted significance levels determined by the Benjamini-Hochberg method, reveal that none of the comparisons between samples differ significantly.
Table 6.9. P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with element, motif, and process attributes for the six Lapita samples. Significance is denoted by asterisk. Significance indicates that dentate density, sherd width, and sherd length are significant predictors of attributes and must be controlled for in subsequent analysis.

Using Fischer’s Exact test, the frequency of elements ($p=0.000$), motifs ($p=0.000$), and processes ($p=0.000$) vary between groups. Individual Fischer’s Exact tests between each group pair indicate which samples differ (Table 6.10). For element frequency, the only samples that do not differ are Early Tonga, Late Tonga, and East Fiji, along with West Fiji and New Caledonia (Fig. 6.8). For motif frequency, Late Tonga does not differ from any group except for Vanuatu; all other sample comparisons differ significantly (Fig. 6.9). For process frequency, New Caledonia differs from Early Tonga, East Fiji and Vanuatu; no other sample comparisons differ significantly (Fig. 6.10). However, given that element, motif, and process frequency are calculated by recording more than one observation per sherd, the assumption of independence is violated for Fischer’s Exact test. Results, therefore, must be interpreted with caution. For this reason, contingency tables are provided as an additional medium for comparing sample groups (Tables 6.11, 6.12, 6.13).
<table>
<thead>
<tr>
<th>Attributes</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha=0.037$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.007$), New Caledonia ($p=0.001$), Vanuatu ($p=0.003$)</td>
<td>West Fiji ($p=0.012$), New Caledonia ($p=0.002$), Vanuatu ($p=0.000$)</td>
<td>Early Tonga ($p=0.007$), Late Tonga ($p=0.012$), East Fiji ($p=0.011$), Vanuatu ($p=0.035$)</td>
<td>West Fiji ($p=0.011$), Late Tonga ($p=0.001$), New Caledonia ($p=0.020$), Vanuatu ($p=0.001$)</td>
<td>Early Tonga ($p=0.001$), Late Tonga ($p=0.002$), East Fiji ($p=0.020$), Vanuatu ($p=0.000$)</td>
<td>Early Tonga ($p=0.003$), Late Tonga ($p=0.000$), West Fiji ($p=0.035$), East Fiji ($p=0.001$), New Caledonia ($p=0.000$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.816$), East Fiji ($p=0.351$)</td>
<td>Early Tonga ($p=0.816$), East Fiji ($p=0.379$)</td>
<td>New Caledonia ($p=0.061$)</td>
<td>Early Tonga ($p=0.351$), Late Tonga ($p=0.379$)</td>
<td>West Fiji ($p=0.061$)</td>
<td></td>
</tr>
<tr>
<td><strong>Motif frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha=0.037$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>West Fiji ($p=0.010$), East Fiji ($p=0.008$), New Caledonia ($p=0.002$), Vanuatu ($p=0.000$)</td>
<td>Vanuatu ($p=0.001$)</td>
<td>Early Tonga ($p=0.010$), East Fiji ($p=0.001$), New Caledonia ($p=0.001$), Vanuatu ($p=0.015$)</td>
<td>Early Tonga ($p=0.008$), West Fiji ($p=0.001$), New Caledonia ($p=0.001$), Vanuatu ($p=0.000$)</td>
<td>Early Tonga ($p=0.002$), West Fiji ($p=0.001$), East Fiji ($p=0.001$), Vanuatu ($p=0.001$)</td>
<td>Early Tonga ($p=0.000$), Late Tonga ($p=0.001$), West Fiji ($p=0.015$), East Fiji ($p=0.000$), New Caledonia ($p=0.001$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.747$)</td>
<td>Early Tonga ($p=0.747$), East Fiji ($p=0.406$), West Fiji ($p=0.136$), New Caledonia ($p=0.583$)</td>
<td>Late Tonga ($p=0.136$)</td>
<td>Late Tonga ($p=0.406$)</td>
<td>Late Tonga ($p=0.583$)</td>
<td></td>
</tr>
<tr>
<td>Attributes</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>New Caledonia</td>
<td>Vanuatu</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Process frequency</strong> $\alpha=0.01$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>New Caledonia ($p=0.001$)</td>
<td></td>
<td></td>
<td>New Caledonia ($p=0.000$)</td>
<td>Early Tonga ($p=0.001$), East Fiji ($p=0.000$), Vanuatu ($p=0.000$)</td>
<td>New Caledonia ($p=0.000$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Late Tonga ($p=0.561$), West Fiji ($p=0.130$), East Fiji ($p=0.519$), Vanuatu ($p=0.030$)</td>
<td>Early Tonga ($p=0.561$), East Fiji ($p=0.149$), West Fiji ($p=0.759$), New Caledonia ($p=0.028$), Vanuatu ($p=0.030$)</td>
<td>Early Tonga ($p=0.130$), Late Tonga ($p=0.759$), East Fiji ($p=0.033$), New Caledonia ($p=0.040$), Vanuatu ($p=0.048$)</td>
<td>Early Tonga ($p=0.519$), Late Tonga ($p=0.149$), West Fiji ($p=0.033$), Vanuatu ($p=0.027$)</td>
<td>Late Tonga ($p=0.028$), West Fiji ($p=0.040$)</td>
<td>Early Tonga ($p=0.030$), Late Tonga ($p=0.030$), West Fiji ($p=0.048$), East Fiji ($p=0.027$)</td>
</tr>
</tbody>
</table>

Table 6.10. Post-hoc comparisons resulting from individual Fischer’s Exact tests between sample groups from the Eastern, Western, and Southern Lapita Provinces. The $\alpha$ value was determined using the Benjamini-Hochberg method and is provided after the attribute name.
Figure 6.8. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Element code refers to that shown in Table 4.2.
Figure 6.9. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Motif code refers to that in Poulsen (1987), Mead et al. (1975), and Anson (1981).
Figure 6.10. Mosaic plot of process frequency by sample group. The vertical length of each rectangle is proportional to the proportions of process type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each process type for the combined sample groups. Sample group 1 represents Early Tonga, sample 2 represents Late Tonga, sample 3 represents West Fiji, sample 4 represents East Fiji, sample 5 represents New Caledonia, and sample 6 represents Vanuatu. Process code refers to that found in Sharp (1988).
<table>
<thead>
<tr>
<th>Count</th>
<th>Total %</th>
<th>Sample group</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count Total %</td>
<td>Sample group</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>New Caledonia</td>
<td>Vanuatu</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>22.9</strong></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td><strong>6.1</strong></td>
<td></td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>12</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.36</td>
<td>0.36</td>
<td>1.25</td>
<td>1.43</td>
<td>2.14</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td><strong>6.2</strong></td>
<td></td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.36</td>
<td>0.36</td>
<td>1.60</td>
<td>1.96</td>
<td>2.32</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td><strong>6.3</strong></td>
<td></td>
<td>8</td>
<td>8</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.43</td>
<td>1.43</td>
<td>0.71</td>
<td>2.14</td>
<td>0.36</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td><strong>6.4</strong></td>
<td></td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.71</td>
<td>0.89</td>
<td>0.36</td>
<td>0.89</td>
<td>1.07</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td><strong>7</strong></td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.18</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>76</td>
<td>62</td>
<td>99</td>
<td>96</td>
<td>116</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.55</td>
<td>11.05</td>
<td>17.65</td>
<td>17.11</td>
<td>20.68</td>
<td>19.96</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.11. Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. The element symbol refers to the updated Chiu and Sand (2005) code presented in Table 4.2.
<table>
<thead>
<tr>
<th>Count Total</th>
<th>Sample group</th>
<th>Early Tonga</th>
<th>Late Tonga</th>
<th>West Fiji</th>
<th>East Fiji</th>
<th>New Caledonia</th>
<th>Vanuatu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motif</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>11 3.93</td>
<td>7 2.50</td>
<td>3 1.07</td>
<td>7 2.50</td>
<td>5 1.79</td>
<td>4 1.43</td>
<td>37 13.21</td>
</tr>
<tr>
<td>A129 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>2 0.71</td>
<td>2 0.71</td>
<td></td>
</tr>
<tr>
<td>A131 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>2 0.71</td>
<td>3 1.07</td>
<td></td>
</tr>
<tr>
<td>A134 (Anson)</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td></td>
</tr>
<tr>
<td>A242 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>1 0.36</td>
<td></td>
</tr>
<tr>
<td>A277 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>1 0.36</td>
<td></td>
</tr>
<tr>
<td>A283 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td></td>
</tr>
<tr>
<td>A427 (Anson)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>1 0.36</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1 0.36</td>
<td>5 1.79</td>
<td>3 1.07</td>
<td>7 2.50</td>
<td>19 6.79</td>
<td>4 1.43</td>
<td>39 13.93</td>
</tr>
<tr>
<td>C</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>1 0.36</td>
</tr>
<tr>
<td>D</td>
<td>3 1.07</td>
<td>2 0.71</td>
<td>8 2.86</td>
<td>2 0.71</td>
<td>3 1.07</td>
<td>1 0.36</td>
<td>19 6.79</td>
</tr>
<tr>
<td>DE1 (Mead)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
</tr>
<tr>
<td>DE1.1 (Mead)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>1 0.36</td>
</tr>
<tr>
<td>DE3 (Mead)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>1 0.36</td>
<td>3 1.07</td>
</tr>
<tr>
<td>DE5 (Mead)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>1 0.36</td>
</tr>
<tr>
<td>DE8 (Mead)</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>1 0.36</td>
</tr>
<tr>
<td>DZC (Mead)</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>0 0.00</td>
<td>0 0.00</td>
<td>2 0.71</td>
</tr>
<tr>
<td>E</td>
<td>0 0.00</td>
<td>1 0.36</td>
<td>2 0.71</td>
<td>0 0.00</td>
<td>4 1.43</td>
<td>2 0.71</td>
<td>9 3.21</td>
</tr>
<tr>
<td>F</td>
<td>3 1.07</td>
<td>3 1.07</td>
<td>3 1.07</td>
<td>0 0.00</td>
<td>7 2.50</td>
<td>0 0.00</td>
<td>16 5.71</td>
</tr>
<tr>
<td>G</td>
<td>2 0.71</td>
<td>2 0.71</td>
<td>2 0.71</td>
<td>1 0.36</td>
<td>4 1.43</td>
<td>0 0.00</td>
<td>11 3.93</td>
</tr>
<tr>
<td>Sample group</td>
<td>Motif</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>New Caledonia</td>
<td>Vanuatu</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td>GZ1 (Mead)</td>
<td></td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.07</td>
<td>0.71</td>
<td>1.07</td>
<td>2.14</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>GZ2 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.71</td>
<td>0.00</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.07</td>
<td>0.71</td>
<td>0.71</td>
<td>1.43</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>J</td>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.36</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>1.79</td>
<td>0.71</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.36</td>
<td>0.36</td>
<td>1.43</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M1 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M10 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M16 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M18 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M19 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>1.07</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>M2.1 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M29 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.43</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M3 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M30 (Mead)</td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.36</td>
</tr>
<tr>
<td>M32 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>M34 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>M35 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.36</td>
<td>0.71</td>
</tr>
<tr>
<td>M42 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.36</td>
</tr>
<tr>
<td>M44 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.36</td>
</tr>
<tr>
<td>M7 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Motif</td>
<td>Sample group</td>
<td>Early Tonga</td>
<td>Late Tonga</td>
<td>West Fiji</td>
<td>East Fiji</td>
<td>New Caledonia</td>
<td>Vanuatu</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>-----------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>N1.1 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.00</td>
<td>0.71</td>
</tr>
<tr>
<td>O</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.36</td>
<td>0.36</td>
<td>1.07</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.43</td>
<td>1.07</td>
<td>0.00</td>
<td>1.79</td>
<td>1.79</td>
<td>17</td>
</tr>
<tr>
<td>Q</td>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>1.79</td>
</tr>
<tr>
<td>R</td>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
</tr>
<tr>
<td>RZ1 (Mead)</td>
<td></td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.71</td>
<td>0.00</td>
<td>0.71</td>
<td>0.00</td>
<td>0.00</td>
<td>1.43</td>
</tr>
<tr>
<td>RZ2 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>2.71</td>
</tr>
<tr>
<td>RZ3 (Mead)</td>
<td></td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>1.79</td>
<td>0.00</td>
<td>0.00</td>
<td>2.86</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>TB3.3 (Mead)</td>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.36</td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.07</td>
<td>0.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.43</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>39</td>
<td>31</td>
<td>52</td>
<td>47</td>
<td>74</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.93</td>
<td>11.07</td>
<td>18.57</td>
<td>16.79</td>
<td>26.43</td>
<td>13.21</td>
</tr>
</tbody>
</table>

Table 6.12. Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system.
Table 6.13. Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. The process symbol refers to those used in the Sharp (1988) system.

6.3. Discussion

The above results indicate that regions within the Eastern Lapita Province share similarities with the west and south. West Fiji is differentiated from East Fiji/Tonga based on greater similarity to outside samples than to those within the Eastern Lapita Province. Based on this, the null hypothesis for Case Study 2:

*The distribution of elements/motifs and structural attributes of Lapita design do not vary between the Eastern, Western, and Southern Lapita Provinces*

is rejected. West Fiji, East Fiji, Early Tonga, Late Tonga, Vanuatu, and New Caledonia assemblages do differ significantly to varying degrees for several attributes. Discrepancy exists between structural versus element/motif attributes, which may be due to the
limited sample size, or may suggest difference in the way design is selected and subsequently applied to a vessel surface. Regardless of the reason, this case study reaffirms the conclusion from Case Study 1; the Eastern Lapita Province is not a cohesive stylistic region, given differences in the way design is applied to the vessel surface.

Results for continuous attributes indicate that density is a significant predictor of Leica attributes and most LEXT attributes, aside from surface area and width; for the latter, sherd length and width are significant predictors. Dentate density, sherd length, and sherd width are also significant predictors of the number of elements, motifs, and processes per sherd. As in the previous study, this has important implications for Lapita design analysis. Given that these variables play a role in predicting the size and shape of dentate stamping, along with the frequency of elements, motifs, and processes, they should be incorporated as covariates for comparison of both structural and element/motif attributes between regions.

Dentate density differs significantly between groups. However, there is no difference between East Fiji and Early Tonga/Late Tonga, Early Tonga/New Caledonia, and Vanuatu/West Fiji. This suggests that East Fiji/Late Tonga have design that is less densely applied than for New Caledonia/Early Tonga or Vanuatu/West Fiji, with Vanuatu/West Fiji having the highest density of design application.

All Leica attributes differ significantly between groups. However, post-hoc comparisons indicate that, for spacing 2, there are no significant differences between groups, which is likely due to the fact that density is controlled for. The general trend is that East Fiji and Late Tonga are most similar, whereas, West Fiji is more similar to New Caledonia and Vanuatu than to East Fiji or Tonga. Early Tonga also shares some similarity in attribute distribution with New Caledonia.

For LEXT attributes, only dentate length, area, and surface area differ between groups. Overall, results indicate that Early Tonga/New Caledonia, along with East Fiji/Late Tonga are most similar. West Fiji is also similar to Vanuatu, aside from area measurements. The greatest differences occur when East Fiji is compared to New Caledonia, Vanuatu, and West Fiji, and when West Fiji is compared to Late Tonga.
The categorical variables of symmetry, zone direction, and motif infilling differ significantly between groups, but lime-filling does not. For symmetry, New Caledonia differs from all groups, and for zone direction, Vanuatu differs from all groups. This may suggest that these particular attributes developed in isolation after initial settlement, or may reflect small sample and sherd size used for analysis. Motif infilling suggests that Early Tonga is most similar to New Caledonia and East Fiji, West Fiji is most similar to New Caledonia and Vanuatu, and East Fiji is most similar to Early and Late Tonga. This could potentially signal interaction between Early Tonga/New Caledonia and between West Fiji/New Caledonia/Vanuatu. East Fiji and Early and Late Tonga also show evidence of potential interaction as previously shown in Case Study 1. However, this patterning could also represent common ancestry or temporal variation.

The number of elements, motifs, and processes per sherd differ. However, post-hoc comparisons indicate that none of the comparisons are statistically significant. Element, motif, and process frequency, however, do differ significantly between groups. Aside from element frequency, results appear to contradict, or at least, not confirm, those for continuous attributes. This could be due to the likely effect that dentate density and sherd size have on these variables, highlighting the importance of controlling for both sherd size and dentate density in Lapita design analysis. A visual comparison of frequency tables provides more in common with results from structural analysis. For element frequency, West Fiji, New Caledonia, and Vanuatu have the highest diversity and Early Tonga/West Fiji and West Fiji/Vanuatu share the greatest number of element types, although not by a large margin. For motif frequency, again, West Fiji, Vanuatu, and New Caledonia appear the most diverse in terms of the number of motif types present in each assemblage. Here, Early Tonga/New Caledonia and West Fiji/Vanuatu/New Caledonia share the greatest number of motif types. Finally, process frequency appears most diverse for New Caledonia and Vanuatu, which makes sense given that these regions are generally assumed to have been settled before either West Fiji or East Fiji/Tonga (Petchey et al. 2015).

Structural attributes indicate that the Vanuatu sample almost always differs from East Fiji, Early Tonga and Late Tonga. New Caledonia also almost always differs from East Fiji. This suggests that there is difference in the structural application of design
between East Fiji, Early Tonga, and Late Tonga from the west and for several attributes, from the south as well. The difference between each region is greater than the difference within, as indicated through positive F-ratios above 1. This suggests that regions are cohesive units, however, given that the Eastern Lapita Province is broken up into four separate regions, it is difficult to evaluate if it represents a cohesive province from this measure. Post-hoc tests of structural attributes, however, would suggest otherwise.

Results from element/motif analysis are not clear cut and do not consistently reaffirm the similarities/dissimilarities between groups as determined through structural attributes. This may suggest that these two aspects of design have different transmission histories. Alternatively, it may indicate that the methods that currently exist to identify and label elements and motifs require unification, as is currently being done for the Lapita region (Chiu and Sand 2005). Until such a system is in place, the question of how structural and element/motif attributes were passed within and between generations is difficult, if not impossible, to adequately answer.

Overall, results for Case Study 2 indicate that in terms of the structural application of design, New Caledonia appears closer to Early Tonga, whereas Vanuatu appears closer to West Fiji. East Fiji and Late Tonga are most similar for the attributes analyzed here. Interestingly, West Fiji is more similar to Vanuatu than to East Fiji and Tonga. Early Tonga is also similar to New Caledonia for several attributes. This is either a reflection of temporal variation, or a signal that, at least for early settlements, Lapita potters from Teouma (Vanuatu) interacted with those in West Fiji, while potters in WLO013A (New Caledonia) interacted with potters in Early Tonga. Additionally, this patterning could indicate common ancestry or an indication that initial settlers in West Fiji arrived from Teouma, while those in Early Tonga may have arrived from New Caledonia. In order to differentiate between these multiple competing hypotheses, other lines of evidence need to be consulted, along with increased sample sizes and a database capable of recording structural and motif attributes in a standardized manner. Despite the current lack of a complete database and standardized approach to analyzing Lapita design, the analysis presented here indicates that West Fiji is clearly differentiated from its Eastern Lapita counterparts. The Eastern Lapita “Province” requires redefinition.
Chapter 7.

Case Study 3 - A View from Within: Lapita Design Through Time in the Tongan Archipelago

The purpose of the third case study is to apply the new approach in more fine-grained detail to an expanded number of archaeological sites within Tonga. The precise dating provided by coral branch files and Bayesian modeling of radiocarbon dates for this region (Burley et al. 2012; 2015), makes it an ideal case for tracking change in attribute application through time. Attribute distribution will be compared to understand design variation in a region that is hypothesized to have interacted from initial settlement throughout later prehistory, based on evidence of obsidian distribution from a northern Tongan source found throughout the archipelago (Burley et al. 2011). Given the presence of western Lapita style ceramic sherds at Nukuleka and their absence elsewhere in the archipelago, it is likely that difference in design will be apparent. If difference in attribute distribution is found, the next step is to determine if attribute type plays a role, more specifically, if structural attributes provide a pattern that is inconsistent with element/motif attributes. Below I outline the methods used to select archaeological samples, along with the results from statistical analysis and a discussion of results.

7.1. Methods

As indicated in Chapter 4 (Table 4.1), 17 quantitative and qualitative attributes were recorded for each sample within Tonga. The Tongan archipelago is composed of three island groups – Tongatapu, Ha’apai, and Vava’u, plus northern and southern outliers (Fig. 7.1). In this study, a sample of 25 sherds each is used to represent the areas of Nukuleka, Ha’ateiho (both on Tongatapu), Ha’apai, and Vava’u. Several archaeological sites are sampled from to understand ceramic variation (Fig. 7.1). The archaeological sites will be discussed, followed by a brief outline of attribute analysis.
Figure 7.1. Island groups in the Tongan archipelago. Archaeological sites sampled from the island groups of Tongatapu, Ha'apai, and Vava'u in this case study are outlined.
7.1.1. Archaeological Samples

A recent re-analysis of radiocarbon dates, short-lived wood charcoal dates, and U/Th dates on coral artifacts, through Bayesian modeling indicates that Lapita settlers colonized Tongatapu by 2838 ± 8 cal BP (U/Th 11-36) and moved north into Ha’apai and Vava’u within 70-90 years (Burley et al. 2015). Despite Vava’u being 130 km north of Hapa’ai, the model places settlement for both regions at a statistically identical time frame (Burley et al. 2015:7). The model also indicates that the Lapita period lasts for 129-158 years in Tongatapu, 32-49 years in Ha’apai, and 51-81 years in Vava’u (Burley et al. 2015). Given this estimated occupation range, and hypothesizing a single generation as 20 years, analysis of ceramic design throughout this region will shed light on similarity/dissimilarity in design application within a few generations following initial occupation. Such rapid exploration throughout the region was likely aided by strong southeast tradewinds which create a natural northern sailing corridor throughout Tonga (Burley and Connaughton 2007).

The Nukuleka sample, along with Pukotala, Faleloa, Mele Havea, Vaipuna, and Tongoleleka were used as is outlined in the first case study. To supplement these sites, three archaeological sites from the northern islands of Vava’u were sampled: Ofu on Ofu Island, Otea on Kapa Island, and Vuna on Pangaimotu Island. Vuna is the earliest site, dated to 2715 ± 35 cal BP, followed by Otea, dated to 2705 ± 35 cal BP, and finally Ofu, dated to 2625 ± 35 cal BP (Burley et al. 2015). All three sites are located in southern Vava’u, enabling easier access to-and-from Lapita sites in Ha’apai and Tongatapu. Eight sherds from both Otea and Vuna, along with nine from Ofu were randomly sampled from the assemblage catalogue, based on the criteria that each sherd had at least four lines of clearly visible dentate stamping. A smaller sample of ten sherds from Vava’u was analyzed using the LEXT, three from Otea and Vuna and four from Ofu.

In addition to the Vava’u sample, a sample from Ha’atieho was added. Ha’atieho is situated on the southern island of Tongatapu, the same island as the founder settlement of Nukuleka. Ha’atieho dates to 2799 ± 7 cal BP (U/Th 12-10) (Burley et al. 2015), representing a transitional period in between initial Lapita settlement at Nukuleka and northern exploration into Ha’apai and Vava’u. Twenty-five ceramic sherds were randomly sampled from the ceramic catalogue for use with the Leica. It should be noted
that for the Ha’ateiho sample, it was not possible to use the LEXT for analysis due to a malfunction with the microscope. For this reason, Ha’ateiho will be left out of the LEXT analysis in this case study.

The Vava’u and Ha’ateiho samples were compared with those from Ha’apai and Nukuleka to determine change in variation, if any, within and between island groups, both temporally and geographically and to understand design variation/homogeneity during the transition from initial settlement to northern Tongan exploration and occupation.

Lapita sites throughout the Tongan archipelago are fairly homogenous in terms of settlement location and size. Small site size suggests that occupations represent hamlets with two to three residential groups and populations likely in the range of 30-40 people (Burley 1999). All sites from Tongatapu and Ha’apai represent middens and contain evidence of intensive exploitation of immediate surrounding areas (Burley et al. 2001). Small population sizes on isolated islands likely required inter-island voyaging for maintaining social, economic, and political ties (Burley et al. 2001). The three sites from Vava’u sampled from here appear to represent permanent occupations similar to the pattern on Ha’apai, suggesting the possibility of horticultural practice, as is known for Lapita sites on Tongatapu and Ha’apai (Burley 2007). Ofu, Otea, and Vuna represent back beach flat hamlets, each having access to open water, a foraging reef, and “a direct sailing corridor back to a homeland in Ha’apai or Tongatapu” (Burley 2007:194). The likelihood of back-and-forth migration makes Tonga an ideal location to understand change in design application during a very limited timeframe in the order of generations.

7.1.2. Attribute Analysis

Once selected, ceramic samples were analyzed for both structural and element/motif attributes. Attributes were divided into nominal and continuous categories. Nominal variables consist of zone direction, process type, presence/absence of motif infilling, lime, and slip, along with symmetry pattern and element/motif recording. Continuous attributes consist of dentate length, width, area, surface area, depth, volume, spacing (1 and 2), density, and the number of elements/motifs/processes per sherd.
Dentate length, width, density, and spacing measurements were recorded using the Leica. Dentate length and width was also measured using the LEXT, along with dentate area, surface area, depth, and volume. Attribute descriptions are found in Chapter 4 (Table 4.1). Once recorded, attributes were compared between samples in order to determine similarity/dissimilarity in distribution. Statistical methodology is outlined in Chapter 4 (section 4.2.2). Results of statistical analysis are presented below.

7.2. Results

Before comparing continuous attribute distribution between groups, the relationship between attributes and dentate density, sherd length, and sherd width was assessed through a bivariate linear fit regression model (Table 7.1). Results indicate that for Leica attributes, sherd length and width are significant predictors of dentate length and are therefore controlled for in ANCOVA. For dentate width, only dentate density is a significant predictor and is therefore controlled for in ANCOVA. All potential covariates are significant predictors of dentate spacing 2 and are controlled for in ANCOVA. For dentate spacing 1, none of the potential covariates are significant predictors and will not be controlled for in ANOVA. For LEXT attributes, dentate density is a significant predictor of surface area and will be controlled for in ANCOVA; no other potential covariates are significant predictors of LEXT attributes.

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Dentate density</th>
<th>Sherd length</th>
<th>Sherd width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dentate length</td>
<td>0.1534</td>
<td>*0.0208</td>
<td>*0.0410</td>
</tr>
<tr>
<td>Dentate width</td>
<td>*0.0227</td>
<td>0.2317</td>
<td>0.6729</td>
</tr>
<tr>
<td>Dentate spacing 2</td>
<td>*0.0001</td>
<td>*0.0006</td>
<td>*0.0012</td>
</tr>
<tr>
<td>LEXT 4000 attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface area</td>
<td>*0.0357</td>
<td>0.6905</td>
<td>0.3535</td>
</tr>
</tbody>
</table>

Table 7.1: P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with Leica MZ6 attributes for Tongan Lapita samples. Significance is denoted by asterisk and determined at an α level of 0.05.

Histograms for attribute distributions were viewed to access data normality. For Leica attributes, dentate spacing 2 and dentate density require a natural log transformation; all other histograms are normally distributed. For LEXT attributes,
dentate density, volume, and surface area require a natural log transformation; all other histograms are normally distributed.

Before running the ANCOVA model for Leica attributes, the distribution of density between groups was compared through ANOVA. Dentate density differs significantly between groups ($p=0.002$). Post-hoc tests indicate that Nukuleka differs from all groups; no other sample groups differ (Table 7.2) (Fig. 7.2).

<table>
<thead>
<tr>
<th>Dentate density $\alpha=0.025$</th>
<th>Nukuleka</th>
<th>Ha’ateiho</th>
<th>Ha’apai</th>
<th>Vava’u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significantly different from:</td>
<td>Ha’apai ($p=0.0027$), Vava’u ($p=0.0015$), Ha’ateiho ($p=0.0069$)</td>
<td>Nukuleka ($p=0.0069$)</td>
<td>Nukuleka ($p=0.0027$)</td>
<td>Nukuleka ($p=0.0015$)</td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Ha’apai ($p=0.7803$), Vava’u ($p=0.6415$)</td>
<td>Ha’apai ($p=0.8523$), Ha’ateiho ($p=0.7803$)</td>
<td>Ha’apai ($p=0.8523$), Ha’ateiho ($p=0.6415$)</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.2. Post-hoc comparisons of dentate density distribution between four Tongan Lapita samples. Chart indicates which groups differ significantly by indication of statistical $p$ values. Statistical significance is determined at an $\alpha$ level calculated using the Benjamini-Hochberg Method.

Figure 7.2. Least squares means plot for dentate density values. The means are estimated from a linear model and bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho.

The distribution of all Leica attributes, aside from dentate spacing 1, differ significantly between groups, while controlling for appropriate covariates (Table 7.3).
Post-hoc tests, however, indicate that none of the sample comparisons differ significantly for dentate length and spacing 2. Only dentate width differs in post-hoc tests (Table 7.4). Here, Nukuleka and Ha’apai differ, as do Ha’apai and Ha’ateiho (Fig. 7.3). The F ratio obtained from each attribute comparison is above 1, indicating that there is more difference between than within groups (Table 7.3).

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Dentate length</th>
<th>Dentate width</th>
<th>Dentate spacing 1</th>
<th>Dentate spacing 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>p value</em></td>
<td><em>0.0239</em></td>
<td><em>0.0022</em></td>
<td>0.0751</td>
<td><em>0.0001</em></td>
</tr>
<tr>
<td><em>F-ratio</em></td>
<td>2.7304</td>
<td>4.5231</td>
<td>2.3725</td>
<td>9.0135</td>
</tr>
</tbody>
</table>

Table 7.3. P values derived from comparisons of means between the four Tongan Lapita sample groups using ANCOVA. Asterisk indicates statistical significant at an α level of 0.05.

<table>
<thead>
<tr>
<th>Leica MZ6 attributes</th>
<th>Nukuleka</th>
<th>Ha’ateiho</th>
<th>Ha’apai</th>
<th>Vava’u</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dentate width α=0.017</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significantly different from:</td>
<td>Ha’apai (<em>p=0.0021</em>)</td>
<td>Ha’apai (<em>p=0.0065</em>)</td>
<td>Nukuleka (<em>p=0.0021</em>), Ha’ateiho (<em>p=0.0065</em>)</td>
<td></td>
</tr>
<tr>
<td>Not significantly different from:</td>
<td>Vava’u (<em>p=0.2749</em>), Ha’ateiho (<em>p=0.6297</em>)</td>
<td>Nukuleka (<em>p=0.6297</em>), Vava’u (<em>p=0.5138</em>)</td>
<td>Vava’u (<em>p=0.0360</em>)</td>
<td>Nukuleka (<em>p=0.2749</em>), Ha’apai (<em>p=0.0360</em>), Ha’ateiho (<em>p=0.5138</em>)</td>
</tr>
</tbody>
</table>

Table 7.4. Post-hoc comparisons of width distribution between four Lapita samples. Statistical significance is determined at different α levels depending on the attribute analyzed. Adjusted significance values are noted next to the attribute name in the chart. The α values were determined using the Benjamini-Hochberg method.
Fig. 7.3. Least squares means plot for dentate width values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho.

The distribution of all LEXT 4000 attributes do not differ significantly between groups, aside from dentate surface area ($p=0.0001$). Post-hoc tests of surface area indicate that Nukuleka ($p=0.0003$) and Ha’apai ($p=0.0003$) differ from Vava’u, but Nukuleka and Ha’apai do not differ significantly from each other ($p=0.8391$) at the Benjamini-Hochberg adjusted significance level of 0.033 (Fig. 7.4). Results for Ha’ateiho are not currently available.

Fig. 7.4. Least squares means plot for dentate surface area values. The means are estimated from a linear model and adjusted for the covariate of dentate density. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, and sample 7 represents Vava’u.
For nominal variables, zone direction and motif infilling differ significantly between groups, while symmetry and lime filling do not (Table 7.5). Post-hoc tests indicate that for zone direction, Nukuleka and Ha’apai do not differ, neither do Vava’u and Ha’ateiho; all other sample comparisons differ significantly (Table 7.6). For motif infilling, none of the sample comparisons differ significantly.

<table>
<thead>
<tr>
<th>Categorical attributes</th>
<th>Lime filling</th>
<th>Symmetry</th>
<th>Direction of vessel zone</th>
<th>Motif filling</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p ) value</td>
<td>0.825</td>
<td>0.320</td>
<td>*0.000</td>
<td>*0.008</td>
</tr>
</tbody>
</table>

Table 7.5. P values derived from Fischer’s Exact test to determine the significance of association between attributes and ceramic sherds from Tongan Lapita sample groups. Asterisk indicates statistical significance at an \( \alpha \) value of 0.05.

<table>
<thead>
<tr>
<th>Zone direction ( \alpha=0.033 )</th>
<th>Nukuleka</th>
<th>Ha’ateiho</th>
<th>Ha’apai</th>
<th>Vava’u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significantly different from: Vava’u (( p=0.002 )), Ha’ateiho (( p=0.003 ))</td>
<td>Nukuleka (( p=0.003 )), Ha’apai (( p=0.000 ))</td>
<td>Ha’ateiho (( p=0.000 )), Vava’u (( p=0.001 ))</td>
<td>Nukuleka (( p=0.002 )), Ha’apai (( p=0.001 ))</td>
<td></td>
</tr>
<tr>
<td>Not significantly different from: Ha’apai (( p=0.126 ))</td>
<td>Vava’u (( p=0.206 ))</td>
<td>Nukuleka (( p=0.126 ))</td>
<td>Ha’ateiho (( p=0.206 ))</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.6. Post-hoc comparisons of zone direction between four Tongan Lapita samples through individual Fischer’s Exact tests. Chart indicates which groups differ significantly by indication of statistical \( p \) values. Statistical significance is determined at an \( \alpha \) level calculated using the Benjamini-Hochberg Method.

For the analysis of elements, motifs, and processes, both the number per sherd and frequency were compared between groups. For the number of elements, motifs, and processes per sherd, the distribution of the attributes was first assessed through observation of histograms. The number of elements and motifs per sherd are not normally distributed, but resulting residuals are. Before comparing attribute distribution between groups, the relationship between attributes and dentate density, sherd length, and sherd width was first assessed through a bivariate linear fit regression model (Table 7.7). Results indicate that density, sherd length, and sherd width are significant predictors of the number of motifs/sherd and processes/sherd. For the number of elements/sherd, only dentate density is a significant predictor.
Table 7.7. P values derived from bivariate linear fit regression between dentate density, sherd length, and sherd width with element/motif/process attributes for Tongan Lapita samples. Significance is determined at an \( \alpha \) level of 0.05 and is denoted by an asterisk.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Dentate density</th>
<th>Sherd length</th>
<th>Sherd width</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Elements/sherd</td>
<td>*0.001</td>
<td>0.1638</td>
<td>0.1034</td>
</tr>
<tr>
<td>#Motifs/sherd</td>
<td>*0.0393</td>
<td>*0.0236</td>
<td>*0.0123</td>
</tr>
<tr>
<td>#Processes/sherd</td>
<td>*0.0095</td>
<td>*0.0454</td>
<td>*0.0160</td>
</tr>
</tbody>
</table>

ANCOVA indicates that the number of elements/sherd (\( p=0.0003 \)), the number of motifs/sherd (\( p=0.0069 \)), and the number of processes per sherd (\( p=0.0001 \)) differ significantly between samples. Post-hoc tests indicate that no sample comparisons differ significantly for the number of elements/sherd and motifs/sherd, but Vava’u differs from Nukuleka (\( p=0.0057 \)), Ha’apai (\( p=0.0012 \)), and Ha’ateiho (\( p=0.0055 \)) for the number of processes/sherd (Fig. 7.5). Using Fischer’s Exact test, the frequency of elements (\( p=0.556 \)) (Fig. 7.6), motifs (\( p=0.301 \)) (Fig. 7.7), and processes (\( p=0.660 \)) (Fig 7.8) do not differ significantly between samples. However, given that element/motif/process frequency is calculated by recording more than one observation per sherd, the assumption of independence is violated for Fisher’s Exact test; results must be interpreted with caution. For this reason, contingency tables are provided for comparing sample groups (Tables 7.8, 7.9, 7.10).

Figure 7.5. Least squares means plot for the number of processes per shed. The means are estimated from a linear model and adjusted for the covariate of dentate density, sherd length, and sherd width. Bars represent 95% confidence intervals. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho.
Figure 7.6. Mosaic plot of element frequency by sample group. The vertical length of each rectangle is proportional to the proportions of element type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each element type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. Element code refers to that in Table 4.2.
Figure 7.7. Mosaic plot of motif frequency by sample group. The vertical length of each rectangle is proportional to the proportions of motif type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each motif type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha‘apai, sample 7 represents Vava‘u, and sample 8 represents Ha‘ateiho. Motif code refers to that outlined in Chapter 4.
Figure 7.8. Mosaic plot of process frequency by sample group. The vertical length of each rectangle is proportional to the proportions of process type in each sample group. Proportions on the x-axis represent the number of observations for each level of sample group. Proportions on the y-axis represent the overall proportions of each process type for the combined sample groups. Sample group 1 represents Nukuleka, sample 2 represents Ha’apai, sample 7 represents Vava’u, and sample 8 represents Ha’ateiho. Process code refers to that outlined in Sharp (1988).
<table>
<thead>
<tr>
<th>Count Total %</th>
<th>Sample group</th>
<th>Nukuleka</th>
<th>Ha’apai</th>
<th>Vava’u</th>
<th>Ha’ateiho</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.8. Frequency counts and percentages for element type in each sample group. First number in each box represents the count and the second number represents the percentage. Element code refers to the updated Chiu and Sand (2005) system presented in Chapter 4.
<table>
<thead>
<tr>
<th>Count Total %</th>
<th>Sample group</th>
<th>Motif</th>
<th>Nukuleka</th>
<th>Ha’apai</th>
<th>Vava’u</th>
<th>Ha’ateiho</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A134 (Anson)</td>
<td>1</td>
<td>0.71</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>1</td>
<td>0.71</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>3</td>
<td>2.13</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DZC (Mead)</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>3</td>
<td>2.13</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
<td>2</td>
<td>1.42</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GZ1 (Mead)</td>
<td>3</td>
<td>2.13</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>3</td>
<td>2.13</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J</td>
<td>1</td>
<td>0.71</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M30 (Mead)</td>
<td>1</td>
<td>0.71</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>4</td>
<td>2.84</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q</td>
<td>1</td>
<td>0.71</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RZ1 (Mead)</td>
<td>2</td>
<td>1.42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TB3.3 (Mead)</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Z</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 7.9. Frequency counts and percentages for motif type in each sample group. First number in each box represents the count and the second number represents the percentage. Where not otherwise stated, the motif symbol refers to those used in the Poulsen (1987) system.

<table>
<thead>
<tr>
<th>Process</th>
<th>Nukuleka</th>
<th>Ha'apai</th>
<th>Vava'u</th>
<th>Ha'ateiho</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS</td>
<td>5 2.79</td>
<td>2 1.12</td>
<td>4 2.23</td>
<td>4 2.23</td>
</tr>
<tr>
<td>HDM</td>
<td>0 0.00</td>
<td>1 0.56</td>
<td>0 0.00</td>
<td>1 0.56</td>
</tr>
<tr>
<td>INT</td>
<td>18 10.06</td>
<td>21 11.73</td>
<td>17 9.50</td>
<td>23 12.85</td>
</tr>
<tr>
<td>MR</td>
<td>4 2.23</td>
<td>2 1.12</td>
<td>2 1.12</td>
<td>3 1.68</td>
</tr>
<tr>
<td>RP</td>
<td>25 13.97</td>
<td>22 12.29</td>
<td>9 5.03</td>
<td>16 8.94</td>
</tr>
<tr>
<td>Total</td>
<td>52 29.05</td>
<td>48 26.82</td>
<td>32 17.88</td>
<td>47 26.26</td>
</tr>
</tbody>
</table>

Table 7.10. Frequency counts and percentages for process type in each sample group. First number in each box represents the count and the second number represents the percentage. The process symbol refers to those used in the Sharp (1988) system.

<table>
<thead>
<tr>
<th>Process</th>
<th>Nukuleka</th>
<th>Ha'apai</th>
<th>Vava'u</th>
<th>Ha'ateiho</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS</td>
<td>5 2.79</td>
<td>2 1.12</td>
<td>4 2.23</td>
<td>4 2.23</td>
</tr>
<tr>
<td>HDM</td>
<td>0 0.00</td>
<td>1 0.56</td>
<td>0 0.00</td>
<td>1 0.56</td>
</tr>
<tr>
<td>INT</td>
<td>18 10.06</td>
<td>21 11.73</td>
<td>17 9.50</td>
<td>23 12.85</td>
</tr>
<tr>
<td>MR</td>
<td>4 2.23</td>
<td>2 1.12</td>
<td>2 1.12</td>
<td>3 1.68</td>
</tr>
<tr>
<td>RP</td>
<td>25 13.97</td>
<td>22 12.29</td>
<td>9 5.03</td>
<td>16 8.94</td>
</tr>
<tr>
<td>Total</td>
<td>52 29.05</td>
<td>48 26.82</td>
<td>32 17.88</td>
<td>47 26.26</td>
</tr>
</tbody>
</table>

7.3. Discussion

The above results indicate that potters within the founding settlement of Nukuleka, employed a ceramic style that, while similar in element and motif type, differed from subsequent occupations in the density of design application. Aside from Nukuleka, the later Lapita settlements of Ha'ateiho, Ha'apai, and Vava'u appear almost indistinguishable in terms of design style and application. This has important implications for the role of Nukuleka in Tongan prehistory and subsequent loss of design diversity soon after initial settlement. Based on this, the null hypothesis for Case Study 3:
The distribution of elements/motifs and structural attributes of Lapita design do not vary between Nukuleka, Ha’ateiho, Ha’apai, and Vava’u is rejected. Nukuleka, Ha’ateiho, Ha’apai, and Vava’u assemblages do differ significantly to varying degrees for both structural and element/motif attributes.

Results for continuous attributes indicate that density is a significant predictor of width, spacing 2, surface area, and for the number of elements, motifs, and processes per sherd. Sherd length and width are also significant predictors of length and spacing 2, along with the number of motifs and processes per sherd. As in the previous two case studies, this has important implications for Lapita design analysis. Given that these variables play a role in predicting the size and shape of dentate stamping, along with the frequency of elements and motifs, they should be incorporated as covariates for comparison of both structural and element/motif attributes between regions.

When density of dentate application is compared, Nukuleka appears the most dense and differs from all other groups. Ha’ateiho, Ha’apai, and Vava’u, in contrast, have design that is less densely applied and do not differ in terms of this attribute. This is what is expected, given that Nukuleka has been hypothesized to have western style Lapita ceramics, more densely applied and intricate than eastern style ceramics (Burley and Dickinson 2001, 2010; Burley et al. 2002). This study provides the first attempt to quantify this hypothesized pattern of design complexity. What is of greater importance, perhaps, is the finding that samples from Ha’ateiho, which is situated on the same island as Nukuleka and inhabited within a few generations of first colonization of Tonga, do not differ in terms of the density of design application from sites further north in Ha’apai and Vava’u. Instead of appearing as a transitional assemblage between Nukuleka and Ha’apai/Vava’u, Ha’ateiho, instead, appears contemporary with assemblages further north.

Aside from density, none of the structural attributes measured with the Leica differ significantly between groups, aside from dentate width. For width, no clear pattern emerges. The general trend, then, is that there is no significant temporal tendency for the size of individual dentate tooth impressions to change through time. There is
evidence, however, that, over time, the spacing between individual dentate tooth impressions increases.

For LEXT attributes, only surface area differs between groups. Nukuleka and Ha’apai both differ from Vava’u, but not from each other. As with data provided by the Leica, this suggests that the size and shape of dentate stamping differs little between regions, but the density of application does differ.

For categorical variables, only zone direction differs between groups; motif infilling, symmetry, and lime-filling do not. For zone direction, all groups differ aside from Nukuleka and Ha’apai, and Vava’u and Ha’ateiho. This is likely reflective of sample size and the short time frame of Lapita occupation in Tonga. Given the lack of entire pots to better view symmetry patterns and evidence of lime and motif infilling, it is little wonder that these attributes do not differ significantly.

Element, motif, and process data provide little in the way of difference between groups. Only the number of processes per sherd differs between groups and here, it is Vava’u that differs from Nukuleka, Ha’ateiho, and Ha’apai assemblages. Again, this is not surprising given the limited period of time represented by these samples and the evidence that Vava’u was the last region settled by Lapita potters in Tonga (Burley and Connaughton 2007; Burley et al. 2015).

Despite the lack of difference between groups based on element/motif frequency, as determined through Fischer’s Exact test, a general comparison of frequency tables suggests some potential patterns. For the element frequency table, there is more similarity in the number of element types shared between Ha’apai, Vava’u, and Ha’ateiho, than between Nukuleka and any other region. The motif frequency table indicates that Ha’apai and Vava’u share the greatest number of motif types, while Ha’apai and Ha’ateiho share the least, along with Nukuleka and Vava’u and Nukuleka and Ha’ateiho. Nukuleka also has the highest motif diversity, meaning that there is a greater number of motif types represented in the assemblage. Frequency tables reinforce the idea of Nukuleka as a founder colony and the hypothesis of subsequent interaction between potters in Ha’ateiho, Ha’apai, and Vava’u a century or less after initial settlement in Tonga.
Overall, results for Case Study 3 indicate that the Ha’ateiho, Ha’apai, and Vava’u assemblages share more in common with each other than they do with the Nukuleka sample. This is what is expected from the archaeological evidence, given that Nukuleka was settled first, with subsequent migrations northwards resulting in the settlement of Ha’apai, followed by Vava’u at a similar time period to Ha’ateiho (Burley and Connaughton 2007; Burley et al. 2001, 2015). Variation, however, is mostly indicated through structural attributes. Element/motif analysis largely suggests similarity between all three regions. This is understandable given the short period of time from initial settlement in Tongatapu to settlement in Vava’u and the evidence for back-and-forth migration provided by volcanic glass composition (Burley et al. 2011). However, the fact that structural attributes are able to identify some variation when element/motif attributes cannot, paints an interesting picture. Potters were likely interacting, enough to share or copy elements and motifs, but not to the extent that is required to reproduce the density of design application.
Chapter 8.

Discussion and Conclusion

The three case studies presented above demonstrate that the methods used to study homogeneity/diversity in ceramic design affect the conclusions that are drawn. Both structural and element/motif aspects of design need to be incorporated into a more comprehensive Lapita design system and tested further. Whether the difference between methods is due to sample size, statistical methodology, or difference in the way design is learned and passed within and between generations will be explored throughout this discussion. The implication of these results for the field of Lapita ceramic design analysis will be explored, with emphasis on the usefulness of the Lapita Province categorization, especially with regard to the Eastern Lapita Province. The null hypothesis of this dissertation; namely:

*The ways in which decorative ceramic design is classified into attributes does not impact the conclusions reached about Lapita archaeology when different attributes are compared*

is rejected. Based on the discrepancy in results originating from different ceramic attributes, it is now time to critically evaluate what we can say about interaction in this region based on ceramic design.

This chapter will discuss results from the three case studies, with focus on the implications for the shape and positioning of the Eastern Lapita Province. After a comparison with previous studies in the region and beyond, I will address what the structural approach reveals about Lapita ceramic design analysis in a general sense. This will be followed by a discussion of the potential role of cultural transmission mechanisms in variation between structural versus element/motif results. Finally, the question of, “Where do we go from here” in Lapita ceramic design analysis will be
explored. Taken together, this dissertation provides insight into design variability and perhaps a cautionary tale to archaeologists concerning interpretation of ceramic design attributes, with important implications for Lapita archaeology more specifically.

8.1. The New “Shape” of the Eastern Lapita Province

It is clear from Case Studies 1 and 2 that the previously defined Eastern Lapita Province, consisting primarily of West Fiji, East Fiji, Early Tonga, and Late Tonga, does not make sense from the viewpoint of a combined structural and element/motif approach to Lapita ceramic design analysis. Case Studies 1 and 2 indicate greater similarity overall between East Fiji and Tonga, especially between East Fiji and Late Tonga, to the exclusion of West Fiji. Case Study 2 broadens the picture and suggests that West Fiji is more similar to New Caledonia and Vanuatu than to East Fiji and Late Tonga, although there are some similarities with Early Tonga. These results suggest that East Fiji, Early Tonga, and Late Tonga were part of an interaction sphere that did not include West Fiji. Given that Early Tonga and West Fiji share some similarities both with each other and with New Caledonia, it suggests interaction of some degree between these three regions during the early settlement phase, a common ancestral homeland, or that both West Fiji and Early Tonga were settled by groups from New Caledonia. Whatever the reason, it is clear that after initial settlement in Tonga and East Fiji, it is unlikely that either region continued/began any type of interaction with West Fiji, as far as potters are concerned.

8.1.1. Comparison with Previous Studies from the Eastern Lapita Region

This new view of the Eastern Lapita Province contrasts with the majority of results from previous studies where element/motif frequency is used to the exclusion of structural design analysis (Clark and Anderson 2009; Clark and Murray 2006; Cochrane and Lipo 2010). Using motif frequency and presence/absence from Best’s (1984) data, Clark and Anderson (2009) conclude that that there was “a relatively early dispersal through Fiji to the Lau Islands and Tonga” (Clark and Anderson 2009:420), with continued back and forth migration from East to West Fiji thereafter. Again, using Best’s (1984) data and motif frequency, Clark and Murray (2006) use an unbiased transmission
model to conclude that due to sharing of motifs, East Fiji (Lau) was settled from both West Fiji and Tonga. With yet another use of Best’s (1984) data, Cochrane and Lipo (2010) use cladistic analysis along with NeighborNet and phenetic distance network analysis, to analyze presence/absence of ceramic motifs from various sites in Fiji, Tonga, and Samoa in order to determine population structure among potters. They conclude that there continued interaction after initial settlement between Fiji and Tonga (Cochrane and Lipo 2010). All three of the above studies acknowledge the issue with using motifs analyzed over thirty years ago, along with relying on the un-tested assumption that motif similarity indicates shared transmission histories. Conclusions indicating continued interaction between West and East Fiji after initial settlement, however, are likely not due solely to the previous concerns and exclusion of structural attribute analysis, but also to the difference in statistical methodology used in each study.

A study that supports the findings outlined here provided by structural analysis is that of Best (1984). Utilizing Jaccard and Robinson coefficients of motif presence/absence and frequency, respectively, Best (1984) determined that the degree to which East Fiji and West Fiji interacted during the Lapita period was suspect. He (1984:653) concluded that East Fiji (Lakeba) appeared to have more in common with ceramics from Tonga and Samoa than with ceramics from West Fiji, suggesting, “…a break from the west is substantial and real.” Unlike Clark and Anderson (2009), Clark and Murray (2006), and Cochrane and Lipo (2010), Best’s (1984) interpretation envisions isolation between East Fiji/Tonga and West Fiji occurring relatively early after initial occupation.

Based on the above discrepancy in results for the Eastern Lapita Province, what can we say, if anything, about interaction in this region? Similarity in motifs can result from several factors including common ancestry, non-standardized motif designation/inventories, sample size, and temporal variation, among others. Importantly, the mechanisms through which motifs are passed within and between generations through cultural transmission can also play a role. Ultimately, the question can be asked: are we assuming too much from the limited information we have? We need other lines of evidence alongside motif analysis, including the additional analysis of design structure
and the determination of “novel” or “innovative” attributes that are shared between assemblages. Lapita design data must also be viewed in context by consulting alternative lines of evidence.

Additional evidence comes in the form of linguistic (Geraghty 1983; Pawley and Ross 1995; Pawley and Sayaba 1971) and genetic research (Shipley et al. 2015). These studies support the findings that West and East Fiji/Tonga might not have interacted to the degree that was once assumed, providing clues to the patterns being presented in Case Studies 1 and 2. Linguistic research suggests that West and East Fiji interacted during initial settlement, with East Fiji potentially even settled from West Fiji (Geraghty 1983; Pawley and Ross 1995). However, soon after, there was a distinct break, at least linguistically, between western and eastern language variants. Eastern Fiji then underwent a “period of common development” with languages ancestral to Polynesian languages, including those of Tonga (Geraghty 1983:348). Genetic evidence paints a more complex picture. Maternal DNA from the mitochondria suggest that individuals from East Fiji are more genetically similar to Polynesian populations (i.e. Tongans) than individuals from West Fiji (Shipley et al. 2015). However, paternal DNA suggests that East Fijians are just as similar to Melanesians to the west as West Fijians. If sex-biased admixture took place during the Lapita period, as has been suggested by other genetic studies (Delfin et al. 2012; Kayser et al. 2006) and potters were female, as has been argued for the Lapita period (Marshall 1985), it stands to reason that female potters from East Fiji were interacting, to varying degrees, with potters in Tonga and not with those in West Fiji. This hypothesis requires further testing, which could be aided by the testing of transmission mechanisms through the analysis of both structural and element/motif attributes from assemblages derived from the regions analyzed here.

8.1.2. Comparison with the Western and Southern Lapita Province

Comparison of West Fiji, East Fiji, Early and Late Tonga with assemblages from New Caledonia (Southern Lapita Province) and Vanuatu (Western Lapita Province) provide a more complex picture of initial settlement and subsequent interaction within the Eastern Lapita Province. Based on initial comparison of both structural and element/motif attributes, both Early Tonga and West Fiji share design characteristics
with New Caledonia and, to a more limited extent, Vanuatu. In total, West Fiji shares 8 attributes with New Caledonia and 11 with Vanuatu. Early Tonga shares 7 attributes with New Caledonia and 4 attributes with Vanuatu. East Fiji shares one attribute in common with New Caledonia, and Late Tonga shares two attributes in common with New Caledonia. These trends suggest that West Fiji and Early Tonga share common ancestry with potters from New Caledonia and Vanuatu (at least for West Fiji) and/or were settled from potters originating here. Alternatively, this pattern may be more indicative of temporal variation where West Fiji is settled first from the West and/or potentially South and then potters quickly move eastwards towards Tonga. Following initial settlement, interaction between West Fiji and Tonga decreases. The placement of East Fiji within this scenario is more difficult to ascertain. Either potters from Tonga settled or interacted to a large extent with East Fiji or East Fiji was settled initially from potters moving eastwards from West Fiji and then interaction ceased and potters from East Fiji and Tonga subsequently interacted. The latter scenario would seem to be the most logical given linguistic and genetic evidence as presented for the Eastern Lapita region.

For Western and Southern Provinces, multidisciplinary evidence is more difficult to interpret given that one of the most recent studies on mtDNA in Oceania (Duggan et al. 2014) grouped Fiji with the Cook Islands, Futuna, Niue, Samoa, Tonga, and Tuvalu, while excluding any samples from Vanuatu or New Caledonia. Indeed, Vanuatu and New Caledonia appear to have been left out of all genetic studies on Pacific human phylogeography. This is despite a call for such samples by Kayser and colleagues in 2006 in a study attempting to discern if Polynesians originated in Island Southeast Asia or Melanesia through genetic analysis of Y chromosomes and mtDNA derived from contemporary populations. There is also a lack of aDNA studies across Remote Oceania to provide additional insight (Matisoo-Smith 2015). However, a recent craniometric study on five, almost complete, skulls from an early Lapita context on Vanuatu suggest that there are strong similarities to Chinese, Western Micronesian, and Polynesian cranial features, but not to Australian or northern Melanesian attributes (Valentin et al. 2016). These results are similar to those provided through an analysis of a Late – or post – Lapita individual from West Fiji (Pietrusewsky et al. 1997), along with a Lapita-age cranium from eastern Fiji, derived from a Lapita site with western-style ceramics (Nunn...
et al. 2007). Overall, results suggest cranial similarity between Teouma and West Fiji, albeit, with little indication of whether West Fiji was settled from Vanuatu. It does, however, indicate that Lapita peoples within Vanuatu and West Fiji were derived, morphologically, from a similar ancestor with Island Southeast Asian characteristics. The same cannot be concluded, one way or the other, for East Fiji (Lau) or Tonga given lack of Lapita-age skeletons from these regions. In contrast, two post-Lapita skeletons from the Lapita site in New Caledonia (Pietrusewsky et al. 1998; Valentin 2003) show evidence of northern Melanesian characteristics, as opposed to “Asian” or “Polynesian” ones (Valentin et al. 2016). This, however, does not provide information on founding settlements in New Caledonia, and is explained through the hypothesis of a second migration, late in the Lapita period, from Melanesia to New Caledonia (Valentin et al. 2016). Regardless of this possibility, the data cannot speak to Lapita period occupation in this region.

Linguistic data presents similar conclusions regarding the origins of Lapita peoples in this region. Settlers associated with the Lapita cultural complex spoke variations of an Austronesian language. This language family originated in Southeast Asia, with a proto-form likely centered in Taiwan (Gray et al. 2009; Greenhill et al. 2010; Pawley 2007). The one hundred-eighty languages of Remote Oceania, of which Vanuatu, New Caledonia, Fiji, and Tonga are a part, are associated with the Oceanic subgroup of the Austronesian language family, sharing unique innovations in sounds, morphology, and lexicon (Pawley 2007). Given the likelihood of rapid dispersal from Near to Remote Oceania during the Lapita period, Lapita groups throughout Vanuatu, New Caledonia, Fiji, and Tonga would have likely spoken Proto Nuclear Oceanic, the ancestral form of the Oceanic branch that exists today, as was spoken in the Bismarck Archipelago (Pawley 2007). There is no evidence for higher-order subgroups pointing to any significant linguistic pause in the region encompassing Vanuatu, New Caledonia, Fiji, and Tonga (Pawley 2007). The data, however, is unable to differentiate between settlement episodes and areas of interaction in Vanuatu, New Caledonia, Fiji, and Tonga.

Taking all above evidence from genetic, biometric, and linguistic data into account, it is clear that Vanuatu, New Caledonia, Fiji, and Tonga were all settled by
people belonging to the Lapita cultural complex who spoke a Proto Nuclear Oceanic language variant, likely derived from a prototype in Island Southeast Asia. The migration route followed a relative west-east trajectory originating in the Bismarck Archipelago and spreading east as far as Tonga and Samoa (Sheppard 2011). All areas were likely settled around 3000 BP, give or take a couple of centuries (Petchey et al. 2015), and, thus, were either settled directly from each other in some direction, or from a common ancestor in a yet, undetermined, Lapita region. Beyond this, it is difficult to say from what location West Fiji and East Fiji/Tonga were settled, or the degree of interaction post-settlement with individuals to the west and south.

8.1.3. Interaction in the Tongan Archipelago through Time

Results from Case Study 3 confirm predictions and hypotheses put forth from archaeological evidence for Tongan settlement, namely that Nukuleka was settled first, followed by Ha’ateiho, Ha’apai, and Vava’u (Burley et al. 2015). The earliest potters appear to produce the most complex design, which quickly simplifies and becomes less densely applied (Burley and Dickinson 2001, 2010; Burley et al. 2002). Element/motif analysis suggests that all three regions are relatively similar, likely due to the fact that these attributes do not take into account the application of design.

The complexity and density of dentate application can now be quantified and objectively compared between assemblages through a combined structural/motif approach. The fact that all four sample regions do not differ significantly for at least some of the attributes tested here, suggests that either interaction and/or common ancestry is at play. Archaeological evidence tends to support the former explanation. Analysis of volcanic glass artifacts throughout Tonga indicate that frequent inter-island voyaging throughout the archipelago was common during the Lapita period (Burley et al. 2011). Rapid settlement and interaction throughout the region was likely aided by strong southeast tradewinds which create a natural northern sailing corridor throughout Tonga (Burley and Connaughton 2007).

What is clear from the structural analysis of design is that initial Lapita settlers in the Tongan archipelago arrived in Nukuleka with both decorated pottery and skills for
producing such pottery. This resulted in more densely applied design and increased diversity in terms of motif type than ceramic design found in Ha’ateiho, Ha’apai, or Vava’u. The most recent dates for the region (Burley et al. 2015) suggest that the transition from densely applied motifs to a restricted repertoire applied in an expanded design field occurred within the first forty years after landfall on Tongatapu (Burley et al. 2015).

The abrupt loss of western Lapita ceramic design at Nukuleka, could be due to several factors. The hypothesized ritualized nature of Lapita pottery, as evidenced from large, non-functional, and ornately decorated display vessels (Kirch 1997), along with those found in mortuary (Bedford et al. 2009) and ritualized breaking contexts (Sand 2013), could help to explain the pattern found in Tonga. Loss of density and aspects of the motif repertoire might be explained as an abandonment of the rituals or social protocols associated with these pots during initial settlement. Equally possible, is the explanation that the specialized knowledge required for the appropriate application and use of design might have been lost. Specialized potters who control access to ceramic information have been found in contemporary potting situations in Fiji (LeBlanc 2011, 2012, 2013; Palmer et al. 1968; Recht 2009; Rossitto 1994) and elsewhere in Oceania (Irwin 1985; May and Tuckson 1982; Nojima 2010). The loss of those who hold specialized knowledge has also been argued as the impetus for loss of design complexity in other contemporary and archaeological contexts (Bell 2015; Hardin and Mills 2000). The latter explanation seems most plausible, given the continued retention of simplified design in Ha’ateiho, Ha’apai, and Vava’u, and the assumption that founder canoes would have carried a limited number of Lapita potters with the knowledge capable of producing complex designs. The loss of these potters within decades of initial settlement at Nukuleka could have altered the process of transmission, leaving novice potters without the appropriate ceramic template to learn from, resulting in a decrease in density and limited motif repertoire found in Ha’ateiho, Ha’apai, and Vava’u assemblages.
8.2. What the Structural Approach Reveals about Lapita Ceramic Design Analysis

The field of Lapita design analysis has made great strides since research began in the early 1960s and has set the stage for critically questioning the reliance on element/motif analysis. From the three case studies presented here, it is clear that the analysis of element/motif and structural attributes often provide different results and conclusions when comparing the same samples. Variation in results are likely due to a number of factors, sample size and statistical methods being two possibilities. Another important possibility being difference in the way these two aspects of design are passed within and between generations through social learning. Both element/motif and structural attributes provide important information about ceramic assemblages. A combined approach to analyzing ceramic design, as outlined here, is argued to be preferable as the remainder of this discussion suggests.

8.2.1. The Structural approach and Lapita Design

The structural approach indicates that it is often not the three dimensional measurements of individual dentate stamped teeth that vary, but the length/width and spacing of the teeth. This variation is most evident in comparison of West Fiji with assemblages from East Fiji and Tonga. As shown through results from 3D imaging, the volume and depth of dentate teeth are often similar within and between groups, but the length, width, area, surface area, and spacing between dentate teeth often differ. One exception to this is the attribute of dentate spacing 2, which does not differ between groups. This is likely due to the impact of dentate density on this measure. The more densely applied dentate design is, the smaller the distance between any two dentate-stamped lines. For this reason, dentate spacing 2 is not likely to be useful in a structural approach. Overall, these measures demonstrate that the structural approach is able to quantify diversity in the application of design. This is an aspect of design that received brief attention in the 1970s in Lapita archaeology, and honourable mentions in the past quarter century (Burley et al. 2002; Chiu and Sand 2005; Clark and Anderson 2009; Green 1990), but has not been utilized to measure and record design complexity as has been demonstrated here.
Perhaps one of the more important discoveries from the new structural approach is the degree to which dentate density and sherd size impact other measures of structural and element/motif diversity. A potential explanation for this is that the density of design application and the size of a sherd ultimately limits the spacing between individual tools and the size of the tool available for use by the potter. The size of the sherd also limits the analyst's observation of the tools used. Due to the impact of these variables as predictors of other attributes, they should be tested further and incorporated as covariates in models of Lapita design homogeneity/heterogeneity where appropriate.

Finally, the structural approach outlined here has integrated categorical attributes of design complexity, which are often mentioned and compared in Lapita ceramic design analysis. The presence/absence of motif infilling is a subjective measure, given the degree of difficulty in establishing the basic form of a motif. However, its use here has led to similar results as those obtained from structural continuous attributes. The attributes of lime-filling and slip are likely not important signals of similarity or interaction within or between Lapita regions as indicated here by lack of any significant difference between groups. For this reason, these attributes should not be included in a comprehensive structural approach unless more research is done using increased sample sizes for each region. The final categorical attribute of zone direction suggests some utility, but, again, should be tested further to verify results.

8.2.2. Results in Light of the Element/Motif Approach

When comparing ceramic samples from an element/motif approach exclusively, there appears to be lack of any pattern as compared to results from structural analysis, especially for the Eastern Lapita Province. Below are summaries of results from each case study for the element/motif approach:

Case Study 1: This study indicates that West Fiji differs from all groups for element frequency. For motif frequency, West Fiji differs from both Early Tonga and East Fiji, but not Late Tonga. Early Tonga also differs from East Fiji. The number of elements/sherd do not differ between groups and for the number of motifs/sherd, only Late Tonga and East Fiji differ.
Case Study 2: For element frequency, Early Tonga, Late Tonga, and East Fiji do not differ. West Fiji and New Caledonia also do not differ, whereas all other sample groups do differ significantly. For motif frequency, Late Tonga does not differ from any group, aside from Vanuatu and all other comparisons differ significantly. For the number of elements and motifs per sherd, none of the sample comparisons differ significantly.

Case Study 3: For element and motif frequency, none of the groups differ. Similarly, for the number of elements/motifs per sherd, there is no difference between groups.

When comparing the above results to those from the analysis of structural attributes, it becomes clear that the element/motif method cannot identify variation related to the application of design. Although there are general similarities to results derived from both approaches, such as the strong similarity in design between East Fiji, Early Tonga, and Late Tonga, the element/motif approach should be supplemented and compared to the structural approach in future Lapita design analysis in order to allow for a more comprehensive understanding of the size and application of design.

8.3. CT Theory: Insights into Design Variation

As indicated above, difference in results provided by structural versus element/motif attributes may be due to several factors, an important one being the way in which different aspects of design are passed within and between generations through social learning. CT theory provides insight into potential mechanisms, or mode (Eerkens and Lipo 2007), of transmission for the results presented here. Ideally, CT theory presents a logical framework and methodological focus through which to test and rule-out equifinal transmission mechanisms. However, given the stage at which Lapita ceramic design analysis is currently, including the lack of consensus over motif designation and a complete database for comparing design across the entire Lapita range, any meaningful comparison of Lapita assemblages through CT derived methodology is, arguably, not profitable. The structural attributes introduced here add another layer to the design analytical corpus, which must also be incorporated and applied to more decorated Lapita sherds before data is sufficient for such testing. That
being said, CT theory is still capable of providing potential testable hypotheses for future studies of Lapita ceramic design and can help to shed light on patterns presented here.

CT theory and ethnoarchaeology have suggested that the mechanisms of transmission for different aspects of design, especially motifs versus structural attributes, often vary within and between groups (Arnold 1983; Bowser 2000; Degoy 2008; Friedrich 1970; Gosselain 1992; Graves 1985; Hardin 1983; Matthews et al. 2011). Bowser's (2000) work in Conambo in the Ecuadorian Amazon suggests that pottery production in the domestic context provides a way of signifying political versus ethnic affiliation through the manipulation of different aspects of pottery designs. In order to test the hypothesis that pottery bowls designate political affiliation more strongly than ethnicity, Bowser (2000) statistically analyzed variations in stylistic attributes of 40 pottery bowls to determine which attributes correlate with politics and which correlate with ethnicity. Of the variables analyzed (form, symmetry, framing lines, line width, color, design elements), it was determined that five (symmetry, interior framing lines, exterior framing lines, color, design elements) correlated positively with political affiliation, while one (interior framing lines) correlated positively with ethnicity. Difference in design attributes have also been found amongst Tarascan Greenware ceramicists in San Jose Mexico (Hardin 1983). Hardin (1983) analyzed ceramic painted designs collected during ethnographic analysis in this region. Through interviews, Hardin (1983) discovered that it is the design configuration, the arrangement of one or more kinds of design elements used to fill a design zone, which is the basic unit of design for potters, and not the design elements themselves. My own ethnoarchaeological work in Kadavu, Fiji also highlights difference in the significance attached to elements as opposed to design structure (LeBlanc 2011). Potters in the village of Nalotu, under the guidance of a master potter, choose design elements at random, without attaching significance to the choice. Despite variability in element selection, all elements are placed on the inner rim/lip of each vessel without fail, with potters noting that this is the appropriate area for such decoration to be placed. In this, the structural placement of elements signifies this particular village style, while the element type used, does not.

Archaeological contexts of design transmission reinforces the differences between motifs and structural aspects of design further. Hegmon (1995) takes a
combination of the element/motif and structural approach and applies it to an analysis of ceramic design in the American Southwest during the Early Puebloan period. The structural approach, for her, is a way of describing attributes in terms of the rules used to execute the design, which can then be compared in varying contexts. Hegmon (1995) hypothesizes that because acts of ritual are formalized, rules of design structure should become more formalized when ceramic vessels are associated with ritual events. In order to test this hypothesis, she records design layout, symmetry, and the use of design elements (particularly triangles and parallel lines) and their location on the vessel. She finds that rules associated with the use of design elements are fewer and indicate fewer differences between ceramic assemblages than do rules associated with design layout and symmetry. In another study, Matthews and colleagues (2011) use Turkmen textile designs from previous CT research (Tehrani and Collard 2002, 2009) to test the hypothesis that certain attributes of design, those that are influenced by market demands, have different transmission histories than those that are more likely to be immune from outside influence. Using Bayesian analysis to infer phylogenetic trees, results indicate that different aspects of design have different transmission mechanisms, “comprising two distinct and phylogenetically coherent packages,” meaning that one set of characters is passed within and between generations as a group, in a manner that is separate from the ways in which other characters are transmitted (Matthews et al. 2011:9).

The structural design attributes used in this dissertation can be separated into those that measure tool size and spacing, and those that qualify the application of design elements onto a vessel surface. While all could reflect learned aspects of design, it is those concerned with tool size and spacing that could more precisely suggest individual motor-habits. Motor-habits lead to subconscious variability that can occur early in development, leading to observed difference between individuals (Hill 1977). Learning how to hold a tool and apply it onto a vessel surface results in a type of hand signature (Haeberlin 1919). Such movements will influence the ways in which a potter learns and applies design onto a pot. While some have argued that measuring the size and spacing of design elements can allow archaeologists to identify individuals (Hill 1977), others (Crown 2007) have warned against such an assumption, noting that in ethnographic situations, more than one individual can participate in the production and design of a
single pot. In this sense, it might be more realistic to view tool size and spacing as the work of multiple individuals who may have learned pottery production and the process of design application in a close setting. Nevertheless, the attributes measured here are likely reflective of motor-habits at the micro-level which, once learned through repeated practice (Crown 2007; Gosselain 1992), would be difficult to alter (Hill 1977), especially once a high level of skill had been achieved (Crown 2007).

The difficulty in altering motor-habits once formed, then, leads to the assumption that mimicking such habits would be difficult in comparison to mimicking a given design motif. This may help to explain difference in patterning between design elements/motifs and attributes related to the size of tools and spacing between them analyzed here. As indicated by Minor and Crown (2001:374), ceramic attributes will vary in whether or not they represent motor-habits. Those that are representative of such habits, will lead to decreasing variation within communities of practice and increasing variation between such groups over time and space (Minor and Crown 2001). This reiterates the importance of analyzing several attributes of ceramic variation in order to determine difference in transmission of these attributes through time.

The above studies, indicate that design motifs cannot be taken for granted as aspects of design that signal intensive group interaction. Similarity in elements/motifs can also result from potters copying design on pots already present within a location, or heirloom vessels brought on founding canoes. Importantly, motifs may represent an aspect of design that is transmitted within and between groups through mechanisms that differ from those of structural design characters. Difference in results provided by element/motif versus structural analysis in each case study, then, could be explained as a result of different transmission mechanisms. Testing this hypothesis for Lapita ceramics requires a large comprehensive and standardized database to record elements, motifs, and structural attributes of design for each of the five Lapita Provinces. The database could then be used to test transmission patterns provided by each method through phylogenetic, network, and Bayesian inference. Given that a Lapita ceramic database is currently under construction, such a goal appears attainable in the foreseeable future.
8.4. Where Should Lapita Ceramic Design Analysis go from Here?

Pottery decoration shows the trails of the beginner, the work of the expert, the efforts of the copyist, and the expression of the creator (Anna Shepard 1956:256).

As Carr and Neitzel (1995:17) have stressed, in order to understand design we need to address the factors of biology, cognitive psychology, and art analysis as all contributing to the "complexity of the artisan as a human being." In order to understand how potters applied design and transmitted this information within and between generations, testable hypotheses must be generated based on models derived from diverse disciplines including biology, psychology, anthropology, and ethnoarchaeology. It is not enough to compare elements/motifs without critically questioning what these decorative attributes tell us about the potter. The assumption that the greater the frequency of shared motifs, the greater the degree of interaction between groups (Chiu 2015), needs to be tested. Ethnoarchaeological research on design transmission has made it clear that while motifs may signal degree of potter interaction, they may also diffuse easily between social boundaries (Friedrich 1970; Gosselain 1992, 2000). Structural aspects of design may also signal interaction, perhaps to a different degree than elements/motifs, because structure is an aspect of design that must be learned in a cultural setting (Arnold 1983; Washburn 2001; Van Keuren 1999). As this dissertation has shown, a unified system that includes both element/motif classification and structural attributes to analyze ceramic design is both possible and desirable, it is now up to archaeologists to determine standardized procedures through a comparative approach.

Since the early days of ceramic design analysis in the American Southwest, archaeologists have advocated the combination approach for element/motif and structural analysis (Amsden 1936; Carlson 1961; Colton and Hargrave 1937; Shepard 1956). This early call gave way to the predominant method of element/motif comparisons, often with the argument that ceramic sherds were too small for the analysis of design structure (Canouts 1990). The element/motif approach is no longer the only appropriate method for an assemblage consisting of small sherds; microscopy techniques have enabled the structural application of design to be quantified and easily
compared within and between assemblages as outlined here. Given that ethnoarchaeological studies indicate structural aspects of design to be indicators of social interaction and cultural transmission (Arnold 1984; Bowser 2000; Friedrich 1970; Herbich 1987), it is time for a revival of a combination approach in Lapita ceramic design analysis, as suggested by the methodology introduced in this dissertation, so that debates related to the function and meaning of Lapita design, and design in broader archaeological contexts, can continue to be addressed.

In order to determine the extent to which elements/motifs and structural attributes of ceramic design signal interaction, Lapita archaeologists should use the tenets and methods provided by CT theory. Given that the transmission of design lies at the heart of questions relating to potter interaction, CT theory provides a logical base from which to ask and test hypotheses of Lapita interaction. CT theory provides testable null hypotheses for determining the patterns of design transmission, such as the presence of biased (conformist, indirect, prestige, etc.) and unbiased processes that can shed light on the patterns of transmission between potters (Richerson and Boyd 2005). Without testable hypotheses, patterns of interaction end up as conjecture.

Now that a comprehensive structural approach has been put forth through this dissertation, Lapita archaeologists should soon be able to test mechanisms of transmission and compare patterns offered through element/motif versus structural attributes. Although transmission patterns through a CT framework have been tested with Lapita motifs (Clark and Murray 2006; Cochrane and Lipo 2010), it has been acknowledged that methods for design classification are out of date and lack standardization. The new Lapita database, as outlined in Chiu and Sand (2005), should help to address this issue. This, combined with a database that also records structural design attributes, as outlined here, is the next step forward. Ideally, if a database housing both aspects of design were to be fully functioning, Lapita archaeologists could compare ceramic assemblages more objectively, and begin to answer the questions at the heart of Lapita ceramic design analysis: who interacted with who and to what extent? Before we can answer these questions with ceramic design, we must first question the role that design plays in cultural transmission.
The three case studies presented here are pilot studies introducing a new approach. As with any new approach, this one requires further testing and includes several areas that could be improved upon in future studies. One issue is identifying individual dentate stamped tools and the operational sequences used to apply the tools. The difficulty with this is being able to find a suitable microscope capable of showing the detail provided by laser scanning confocal microscopes, while at the same time having an objective lens large enough to view the entire surface of the tool. It would also be ideal to have control samples to verify precise operational sequences of design application; however, this would require that the same type of clay, temper, and firing conditions be used to replicate pottery production, conditions that are not consistently reproducible for Lapita ceramics. As far as I am aware, no experimental studies exist to understand the impact of clay shrinkage during the firing process on the three dimensional shapes of dentate-stamped tools, but this represents an important area of future research. Another issue is the role of sample size constraints. Future studies should use increased sample sizes to determine the effect of this on statistical results. Finally, future research should help to parse out why differences between the comparison of structural and element/motif attributes exist. Such differences may be due to temporal, spatial, or mechanistic variables of design transmission. Given that the Eastern Lapita Province has been argued as a cohesive interaction sphere, future studies of ceramic design should use available data to determine which of the above factors may lead to the differences outlined here and to test the hypothesis generated through this dissertation that the Eastern Lapita Province is a region where, soon after initial settlement, distinct east and west interaction spheres developed.

8.5. Conclusion

This study has introduced a new structural approach to analyzing Lapita ceramic design that differs from traditional element/motif analysis. This approach utilizes microscopy techniques to quantify the density, layout, and organization of design. Four sample regions from within the Eastern Lapita Province are compared: West Fiji, East Fiji, Early Tonga, and Late Tonga. These regions are analyzed to determine which differ significantly when compared via structural versus element/motif analysis. The main aim
of this analysis was to determine the difference, if any, between methods and to understand if the Eastern Lapita Province represents a cohesive region in terms of ceramic design. In order to understand how regions within the Eastern Lapita Province compare to other Lapita regions, samples from Southern and Western Lapita Provinces were added to the analysis. Finally, to test the new structural approach on a smaller geographical and temporal scale, four well-dated sample regions from within the Tongan archipelago were analyzed.

Results from structural analysis indicate that East Fiji (Lau) has more in common with Tonga than with West Fiji. Results from element/motif analysis suggest similar patterning, but are problematic due to the influence of dentate density and sherd size on the frequency of elements and motifs. When a sample from both the Southern and Western Lapita Province are added into the analysis, it appears that West Fiji is more similar to the southern and western samples than to East Fiji and Late Tonga, although there are some similarities with Early Tonga. These results suggest that East Fiji, Early Tonga, and Late Tonga represent a separate interaction sphere from West Fiji that likely developed soon after initial settlement, potentially from the latter region. When regions within the Tongan archipelago are analyzed exclusively with structural analysis, results suggest that Early Tonga has the most densely applied and complex application of dentate stamping, leading way to simplified and less densely applied design in Ha’ateiho, Ha’apai, and Vava’u, reconfirming evidence from archaeological research. The same samples analyzed solely with element/motif methods suggest relative homogeneity between groups. This is likely due to the fact that this approach cannot isolate difference in the structural application of design. Such results indicate that both structural and element/motif analysis need further testing.

Uncertainty is present in the degree to which elements/motifs and/or structural attributes signal potter interaction. Cultural transmission mechanisms through which potters choose designs and then place them onto a pot vary. These mechanisms have yet to be identified through hypotheses tested with both structural and element/motif ceramic design data employing a single data set. This study presents an important step in this direction for Lapita archaeology. Elements and motifs are no doubt important for the analysis of design, but structural application can and should be used as a
complementary approach, as has been argued elsewhere (Hegmon 1995; Hegmon and Kulow 2005; Van Keuren 1999).

The structural approach introduced here has the ability to quantify the complexity of design application in a way that is easily applied and compared both within cultural regions and in wider cross-cultural perspective. By using microscopy techniques applicable to small ceramic sherds that form the bulk of Lapita archaeological assemblages, it is no longer a requirement that large sherds or even whole pots be present before ceramicists tackle structural analysis. Both approaches should be used to test hypotheses simultaneously so that archaeologists can determine the extent to which either method provides a useful account of interaction, or lack thereof, in the past.

This method has application beyond the field of Lapita archaeology to other forms of decorated pottery and material culture across spatial and temporal boundaries. Future research should focus on testing hypotheses of design transmission by using the structural approach outlined here, along with element/motif analysis.
References

Allen, J., and C. Gosden (editors).

Ambrose, Wallace


Amsden, C. A.

Anson, Dimitri


Arnold, Dean E.


Artal-Isbrand, Paula, and Philip Klausmeyer
Artal-Isbrand, Paula, Philip Klausmeyer, and Winifred Murray
2011 An Evaluation of Decorative Techniques on a Red-Figure Attic Vase from the Worcester Art Museum using Reflectance Transformation Imaging (RTI) and Confocal Microscopy with a Special Focus on the “Relief Line.” MRS Proceedings 1319.

Atkinson, Q. D., A. Meade, C. Venditti, S. J. Greenhill, and M. Pagel

Atran, Scott

Aunger, R.

Aunger, Robert
2003 Cultural Transmission and Diffusion. Encyclopaedia of cognitive science.

Barbrook, Adrian C., Christopher J. Howe, Norman Blake, and Peter Robinson

Barton, C. Michael

Bedford, Stuart

Bedford, Stuart, Matthew Spriggs, Hallie Buckley, Frederique Valentin, and Ralph Regenvanu

Bedford, Stuart, Matthew Spriggs, and Ralph Regenvanu
Bell, Adrian Viliami
2015  Linking Observed Learning Patterns to the Evolution of Cultural Complexity. 

Benjamini, Yoav

Benjamini, Yoav, and Yosef Hochberg

Bentley, R. Alexander, and Stephen J. Shennan

Best, Simon


Bettinger, Robert L., and Jelmer Eerkens

Binford, Lewis R.

Borgerhoff Mulder, Monique, Charles L. Nunn, and Mary C. Towner

Bowser, Brenda J.

Bowser, Brenda J., and John Q. Patton
Boyd, Robert, Monique Borgerhoff Mulder, William H. Durham, and Peter J. Richerson  

Boyd, Robert, and Peter J. Richerson  

Braun, David P.  

Brody, J. J.  

Buchanan, Briggs, and Mark Collard  

Buckley, Christopher D.  

Burley, David, Kevan Edinborough, Marshall Weisler, and Jian-xin Zhao  

Burley, David V.  


Burley, David V., Andrew Barton, Sean P. Connaughton, and Karen Tache

David V., and Sean P. Connaughton

Burley, David V., and William R. Dickinson


Burley, David V., and Kathleen LeBlanc


Burley, David V., Peter J. Sheppard, and Maia Simonin

Burley, David V., Alice Storey, and Jessi Witt

Burley, David, Marshall I. Weisler, and Jian-xin Zhao

Campbell, Donald T.
Campbell, D. T.  

Canouts, V.  

Capone, Patricia W., and Robert W. Preucel  

Carlson, Roy L.  

Carr, C., and Jill E. Nietzel  

Carson, Mike T., Hsiao-chun Hung, Glenn Summerhayes, and Peter Bellwood  


Cavalli-Sforza, Luigi L., and Marcus W. Feldman  

Chernela, Janet  
Chiu, Scarlett


Chiu, Scarlett, and Christophe Sand

Clark, Geoffrey, and Atholl Anderson

Clark, Geoffrey, and Atholl Anderson, eds.

Clark, Geoffrey, and Tim Murray

Clark, Lindsey Renee

Cloak, F. T.

Cochrane, E. E., and C. P. Lipo

Cochrane, Ethan E.


Collard, Mark, and Stephen Shennan

Collard, Mark, Stephen Shennan, C. Buchanan, and Alexander Bentley

Collard, Mark, Stephen J. Shennan, and Jamshid J. Tehrani

Colton, Harold S., and Lyndon L. Hargrave

Conkey, Margaret W., and Christine A. Hastorf

Crowe, Donald W.
Crow, James F., and Motoo Kimura

Crown, Patricia L.

Crown, Patricia L.

Cunningham, Jerimy J.


Darwent, John, and Michael J. O’Brien

David, Bruno, Ian J. McNiven, Thomas Richards, Sean P. Connaughton, Matthew Leavesley, Bryce Barker, and Cassandra Rowe

David, Nicholas, and Carol Kramer

David, Nicholas, Judy A. Sterner, and K. B. Gavua

Dawkins, Richard

DeBoer, Warren R.

Deetz, James D. F.  

Degoy, Laure  

Delfin, F., S. Myles, Y. Choi, D. Hughes, R. Illek, M. van Oven, B. Pakendorf, M. Kayser, and M. Stoneking  

Denham, Tim, Christopher Bronk Ramsey, and Jim Specht  

Dickinson, William R.  

Dickinson, William R., and Patrick D. Nunn  


Dickinson, William R., Richard Shutler Jr., Rob Shortland, David Burley, and Thomas Dye  

Dickinson, William R., and Richard Jr. Shutler  

Donovan, Lorna J.

Duggan, A. T., B. Evans, F. R. Friedlaender, J. S. Friedlaender, G. Koki, D. A. Merriwether, and M. Stoneking

Dunnell, Robert C.

Durham, W. H.

Edinborough, Kevan

Eerkens, Jelmer W., Robert L. Bettinger, and Richard McElreath

Eerkens, Jelmer W., and Carl P. Lipo


Evans, Adrian A., Danielle A. Macdonald, Claudiu L. Giusca, and Richard K. Leach

Ewens, W. J.


Graves, Michael W.

Gray, Michele, and David Albaugh

Gray, R. D., A. J. Drummond, and S. J. Greenhill

Greenhill, Simon J., Alexei J. Drummond, and Russell D. Gray

Green, Roger


Hagerstrand, T.

Hamilton, Marcus J., and Briggs Buchanan

Haour, Anne
Hardin, Margaret A.


Hardin, Margaret A., and Barbara J. Mills

Harmon, Marcel J., Todd L. VanPool, Robert D. Leonard, Christine S. VanPool, and Laura A. Salter

Hart, John. P., and William Engelbrecht

Hays, Kelley Ann

Hegmon, Michele

Hegmon, Michelle


Hegmon, Michelle, and Stephanie Kulow

Heine-Geldern, R.

Henrich, Joseph, and Francisco Gil-White

Herbich, Ingrid

Herbich, Ingrid, and Michael Dietler

Hewlett, B. S., H. N. Fouts, A. H. Boyette, and B. L. Hewlett

Hilgeman, Sherri L.

Hill, James N.

Hogg, Nicholas W. S.

Howe, Christopher J., and Heather F. Windram
Hunt, Terry L.


Irwin, Geoffrey
1985 The Emergence of Mailu: As a Central Place in Coastal Papuan Prehistory. Terra Australis 10. Department of Prehistory, Research School of Pacific Studies, Canberra.

Irwin, Geoffrey, Trevor Henry Worthy, Simon Best, Stuart Hawkins, Jonathan Carpenter, and Sepeti Matararaba

Jernigan, E. W.

Jordan, Peter, and Thomas Mace

Kamp, Kathryn

Kayser, M., Silke Brauer, Richard Cordaux, Amanda Casto, Oscar Lao, Lev Zhivotovsky, Claire Moyse-Faurie, Robb Rutledge, Wulf Schiefendoevel, David Gill, Alice Lin, Peter Underhill, Peter Oefner, Ronald Trent, and Mark Stoneking

Key, Alastair J. M., James W. Stemp, Mikhail Morozov, Tomas Proffitt, and Ignacio de la Torre
Kirch, Patrick V.

Kohler, Timothy A.

Kohler, Timothy A, Stephanie VanBuskirk, and Samantha Ruscavage-Barz

Larsen, Anna W.

Lathrap, Donald W.

LeBlanc, Kathleen


Linton, R.

Lipo, Carl P.

Lipo, Carl P., Mark Collard, Michael J. O’Brien, and Stephen J. Shennan (editors)

Lipo, Carl P., and Jelmer W. Eerkens

Longacre, William A.

Lyman, R. Lee

Lyman, R. Lee, and Michael J. O’Brien

Marshall, Yvonne
Martinsson-Wallin, Helene

Matisoo-Smith, Elizabeth


May, Patricia, and Margaret Tuckson

McGuigan, Nicola, Daryl Gladstone, and Lisa Cook

McNiven, Ian J., Bruno David, Thomas Richards, Ken Aplin, Brit Asmussen, Jerome Mialanes, Matthew Leavesley, Patrick Faulkner, and Sean Ulm

Mead, Sidney M.


Mead, Sidney M., Lawrence Birks, Helen Birks, and Elizabeth Shaw (editors).

Mesoudi, Alex
Mesoudi, Alex, and Andrew Whiten

Mesoudi, Alex, Andrew Whiten, and Robin Dunbar

Miller, Daniel

Mills, Barbara J.

Mills, Barbara J.

Moore, J. H.

Moylan, Jennifer W., Monique Borgerhoff Mulder, Corine M. Graham, Charles L. Nunn, and N. Thomas Hakansson

Munson, Marit K.

Neff, Hector
Neiman, Fraser D.

Nelson, Margaret C., Michelle Hegmon, Stephanie R. Kulow, Matthew A. Peeples, Keith W. Kintigh, and Ann P. Kinzig

Nojima, Yoko

Nunn, Patrick D.


Nunn, Patrick D., and Fiona Petchey

O’Brien, Michael J. (editor).

O’Brien, Michael J., Briggs Buchanan, Mark Collard, and Matthew T. Boulanger

O’Brien, Michael J., R. Lee Lyman, Mark Collard, Russel D. Gray, and Stephen J. Shennan
O’Brien, Michael J., R. Lee Lyman, Alex Mesoudi, and Todd L. VanPool
2010 Cultural Traits as Units of Analysis. Philosophical Transactions of the Royal Society B: Biological Sciences 365: 3797–3806.

Palmer, Bruce, Elizabeth Shaw, Peggy Dickinson, and Meredith Sykes

Pawley, Andrew

Pawley, Andrew, and Malcolm Ross

Pawley, Andrew, and Timoci Sayaba

Peregrine, Peter N.

Petchey, Fiona, Matthew Spriggs, Stuart Bedford, and Frédérique Valentin

Phillips, P., and G. R. Willey

Pietrusewsky, M., J.C. Galipaud, and F. Leach

Pietrusewsky, M., T.L. Hunt, and R.M. Ikehara-Quebral

Pirkirayi, Innocent

Plog, Stephen

Pocklington, Richard

Posada, David, and Keith A. Crandall

Poulsen, Jens

Recht, Jo

Rexova, K

Rice, Prudence M.

Richerson, Peter J., and Richerson Boyd


Riede, Felix

Rossitto, Rosa
Ross, Malcolm, Andrew Pawley, and Meredith Osmond (editors). 
1988 "The Lexicon of Proto Oceanic: The Culture and Environment of Ancestral Oceanic Society." Research School of Pacific and Asian Studies, Australian National University, Canberra, Australia.

Ross, R. M., S. J. Greenhill, and Q. D. Atkinson 

Sackett, James R. 

Sand, Christophe 


Sand, Christophe, Jacques Bole, and Andre Ouetcho 
Sand, Christophe, Scarlett Chiu, and Nicholas Hogg (editors)
2015  *The Lapita Cultural Complex in Time and Space: Expansion Routes, Chronologies and Typologies*. Center for Archaeological Studies, Research Center for Humanities and Social Sciences, Academia Sinica.

Schiffer, Michael Brian

Schiffer, Michael Brian, and James M. Skibo

Sharp, Nancy D.

Shaw, Elizabeth

Shennan, S. J., and J. R. Wilkinson

Shennan, Stephen
1997  *Quantifying Archaeology*. University of Iowa Press, Iowa City.


2013  Demographic Continuities and Discontinuities in Neolithic Europe: Evidence, Methods and Implications. *Journal of Archaeological Method and Theory* 20: 300–311.

Shennan, Stephen J., and Alexander Bentley
Shepard, Anna O.  


Shepard, Peter J.  

Shipley, Gerhard P., Diana A. Taylor, Anand Tyagi, Geetanjali Tiwari, and Alan J. Redd  

Siorat, J.P.  

Skelton, C.  

Soares, Pedro, Teresa Rito, Jean Trejaut, Maru Mormina, Catherine Hill, Emma Tinkler-Hundal, Michelle Braid, Douglas J. Clarke, Jun-Hun Loo, Noel Thomson, Tim Denham, Mark Donohue, Vincent Macaulay, Marie Lin, Stephen Oppenheimer, and Martin B. Richards  

Spaulding, A. C.  

Spriggs, Matthew (editor)  


Stark, Miriam T.  

Stark, Miriam T., Brenda J. Bowser, and Lee Horne


Steele, James, Claudia Glatz, and Anne Kandler

Stemp, James W., Harry J. Lerner, and Elaine H. Kristant

Sterner, Judy A.

Summerhayes, Glenn
2000a  *Lapita Interaction*. Terra Australis 15. Australian National University, Canberra, Australia.


Summerhayes, Glenn, and J. Allen

Tehrani, Jamshid, and Mark Collard

Terrell, John Edward


Terrell, John Edward, Kevin M. Kelley, and Paul Rainbird

Terrell, John Edward, and Esther M. Schechter

Tolstoy, Paul

Valentin, Frédérique

Valentin, Frédérique, Florent Détroit, Matthew J. T. Spriggs, and Stuart Bedford

Van Keuren, Scott

Wallaert, Hélène

Wallaert-Pêtre, Hélène
Washburn, Dorothy (editor).


Washburn, Dorothy K., and Donald W. Crowe (editors).


Washburn, Dorothy K., William N. Washburn, and Petia A. Shipkova

Watson, Patty Jo, and Steven A. LeBlanc

Weissner, Polly

Whalen, Michael E., and Paul E. Minnis

White, J. P., J. Allen, and J. Specht

Wobst, H. M.

Wollstein, Andreas, Oscar Lao, Christian Becker, Silke Brauer, Ronald J. Trent, Peter Nürnberg, Mark Stoneking, and Manfred Kayser
Appendix A.

Ceramic Attribute Data

Sherd Data and Ceramic Attributes:

Below is the file name for data tables that include the catalogue numbers and attribute data recorded for each sherd. Spreadsheets are organized by archaeological region.

File name:

Appendix A – Ceramic Attribute Data.xlsx
Appendix B.

Raw Attribute Data

Below is the file name for data tables that provide raw attribute data for each sample group. These data tables were used to undertake statistical testing.

File name:
Appendix B – Raw Attribute Data.xlsx
Appendix C.

Ceramic Photo Catalogue

Below is the file name for the ceramic photo catalogue. A photo and catalogue number are provided for each sherd analyzed in this dissertation. Photo catalogues are divided into three files, two for Tongan assemblages, and one for West Fiji, East Fiji, Teouma, and New Caledonia samples. Photos from Vanuatu are reproduced with permission from Dr. Stuart Bedford, all other photos were taken by myself, but with permission from those who loaned the ceramic sherds.

**File names:**

Appendix C - West Fiji, East Fiji, Teouma, New Caledonia Photo Catalogue.xlsx

Appendix C - Tonga Photo Catalogue 1.xlsx

Appendix C - Tonga Photo Catalogue 2.xlsx