

**THE ANCIENT WITNESSES
OF THE
EPISTLE TO THE HEBREWS**

**A computer-assisted analysis of the
papyrus and uncial manuscripts of
PROS EBRAIIOUS**

Timothy John FINNEY

BSc, BDiv (Hons.)

A thesis presented for the degree of
Doctor of Philosophy of Murdoch University.

1999

DECLARATION

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary educational institution.

.....

T. J. Finney

ABSTRACT

The text of the Greek New Testament is subject to variation because it was copied by hand for fourteen hundred years. The task of documenting the variation has never been completed because of the enormous number of manuscripts (over five thousand), although several critical editions have made important contributions towards summarising the evidence.

There have been few attempts to record the exact contents of the manuscripts, largely because of the daunting scale of such an undertaking. As a rule, collations which form the basis of critical editions level orthographical variation and apparent errors. By contrast, a complete collation retains these details but requires a greater effort to produce. If the information contained in such features is significant for plotting the history of the text, then complete collation should be the rule rather than the exception.

As a test case for the rest of the New Testament, this thesis sets out to record the ancient text of the epistle to the Hebrews and extract information pertinent to its journey through time and space. Multivariate analysis of a complete collation of the extant papyrus and uncial Greek manuscripts is employed to map the text's trajectories with respect to textual and orthographical variation. When combined with the evidence of the Church Fathers and early versions, the same analysis permits assessment of the degree to which modern editions conform to the ancient text.

TABLE OF CONTENTS

ABSTRACT.....	iii
TABLE OF CONTENTS.....	iv
ACKNOWLEDGMENTS.....	xi
ABBREVIATIONS.....	xvi

THESIS

1	INTRODUCTION.....	1
1.1	The objective of this study.....	1
1.2	Arrangement.....	2
1.3	Nomenclature.....	2
1.4	Notes and references.....	5
1.5	Scribes.....	6
2	SOURCES.....	8
2.1	Primary witnesses.....	9
2.1.1	Identification.....	9
2.1.2	Access.....	10
2.1.3	Photographic collections.....	11
2.1.4	Other resources.....	13
2.2	Supplementary witnesses.....	16
2.2.1	Uncials.....	18
2.2.2	Minuscules.....	18
2.2.3	Lectionaries.....	19
2.2.4	Patristic citations.....	20
2.2.5	Versions.....	21
2.2.6	Authors and editions.....	21
2.2.7	Criteria.....	23
3	TRANSCRIPTION.....	29
3.1	Computer-oriented transcription.....	30
3.1.1	Reveals the hidden.....	30
3.1.2	Conveys the meaning.....	31
3.1.3	Accurate, beautiful, dignified, and clear.....	32
3.1.4	Succinct yet unambiguous.....	32
3.1.5	Contemporary yet future-proof.....	34
3.1.6	Tolerates uncertainty.....	35
3.1.7	Open-ended.....	35
3.1.8	Documented and convenient.....	37
3.2	Transcription system specification.....	39
3.3	Using the Collate transcription system.....	41
3.3.1	Complete transcription.....	41
3.3.2	Basic text.....	41
3.3.3	Location markers.....	42
3.3.4	Diacritics.....	42
3.3.5	Word and line division.....	43
3.3.6	Block markers.....	43
3.3.7	Scribal contractions.....	44
3.3.8	Doubtful and obliterated text.....	45
3.3.9	Spaces, punctuation, breathings, and accents.....	49
3.3.10	Implied original disposition.....	50
3.4	Scribal alteration.....	51
3.5	Summary of specialised tags.....	53
3.6	Referenced notes.....	54

3.7	Error reduction.....	54
3.8	Documentation.....	55
3.9	Archives.....	57
4	COLLATION.....	62
4.1	Definition and purposes.....	63
4.2	Method.....	64
4.3	Peter Robinson's Collate 2.....	65
4.3.1	Preprocessing transcriptions.....	65
4.3.2	Prep: a preprocessing program.....	67
4.3.3	Collation with Collate 2.....	70
4.4	Collation based on a synthetic text.....	71
4.4.1	Filter.....	74
4.4.2	Separate.....	76
4.4.3	Format.....	77
4.4.4	Normalise.....	80
4.4.5	Synthesise.....	83
4.4.6	Matrix.....	86
4.4.7	Report.....	89
4.4.8	Utility programs.....	90
4.4.9	Producing the output desired.....	92
4.5	Transcription revisited.....	94
4.5.1	Serial versus parallel representation.....	94
4.5.2	Normalisation.....	95
4.5.3	Probabilistic treatment of uncertainty.....	99
4.5.4	Parallel mark-up.....	103
5	CLASSICAL SCALING.....	113
5.1	Multivariate analysis.....	114
5.1.1	Definition.....	114
5.1.2	Purposes of multivariate analysis.....	115
5.2	Classical scaling demonstration.....	117
5.2.1	Actual distances.....	117
5.2.2	Data from Gordon D. Fee's study of John 1-9.....	119
5.2.3	Significance of the axes.....	121
5.3	Data matrices.....	125
5.3.1	Notation.....	125
5.3.2	Data types.....	126
5.3.3	Missing data.....	128
5.3.4	Variables not affecting relationships.....	128
5.3.5	The principal data matrices of this study.....	128
5.4	The sample data matrix.....	129
5.4.1	Minuscules.....	132
5.4.2	Versions.....	132
5.4.3	Church Fathers.....	132
5.4.4	Authors and editions.....	134
5.4.5	Critical principles.....	134
5.4.6	Construction of quasi-transcriptions.....	147
5.5	Dissimilarity matrices.....	149
5.6	Similarity coefficients.....	151
5.6.1	Double zeros.....	152
5.6.2	Similarity coefficient adopted for this study.....	153
6	INTERPRETATION.....	169
6.1	Map interpretation.....	170
6.1.1	Focus on textual variation.....	170
6.1.2	Focus on spelling variation.....	171
6.1.3	Focus on other kinds of variation.....	171

6.1.4	Number of axes and explanatory power.....	172
6.1.5	Three-dimensional interpretation.....	173
6.1.6	Number of units.....	173
6.1.7	Proximity.....	175
6.1.8	Convergence, divergence, and trajectories.....	175
6.2	Axis interpretation.....	177
6.2.1	Inherent characteristics.....	177
6.2.2	Association between inherent and familiar characteristics.....	178
6.2.3	Correlation with temporal and geographical measures.....	178
6.2.4	Derived coordinates.....	179
6.2.5	Test witness correlations.....	181
7	RESULTS.....	189
7.1	Textual maps.....	191
7.2	Spelling maps.....	194
7.3	Other maps.....	211
7.4	Correctors.....	217
7.5	Minuscules.....	235
7.6	Versions.....	238
7.7	Church Fathers.....	255
7.8	Authors and editions.....	265
7.9	Criteria.....	268
8	EVALUATION.....	291
8.1	Validity of the Euclidean assumption.....	292
8.2	Stability of the mapping technique.....	293
8.2.1	Binary vs. multistate.....	294
8.2.2	Similarity coefficient.....	297
8.2.3	Dependence on objects.....	298
8.2.4	Dependence on variables.....	299
8.2.5	Block mixture.....	300
8.3	Confidence intervals.....	301
8.3.1	Dissimilarities of unrelated witnesses: binary case.....	301
8.3.2	Dissimilarities of unrelated witnesses: multistate case.....	311
8.3.3	Probability ellipses for witness locations.....	314
8.4	Classification.....	319
8.4.1	Hierarchical trees.....	320
8.4.2	Minimum spanning trees.....	324
8.4.3	Non-hierarchical clustering.....	325
8.4.4	Seriation.....	327
8.4.5	Principal component analysis.....	328
8.4.6	Correspondence analysis.....	330
8.4.7	Canonical variates analysis.....	331
8.4.8	Existing classification methods.....	336
8.4.9	Stemmatic classification methods.....	345
8.4.10	Validity of my classification scheme.....	347
8.5	Collation revisited.....	348
8.5.1	Binary data.....	348
8.5.2	Multistate data.....	351
9	TEXTUAL DEVELOPMENT.....	375
9.1	Selection.....	376
9.1.1	Intentional and unintentional selection.....	376
9.1.2	Rules governing selection.....	377
9.1.3	Scope of selection rules.....	378
9.1.4	Scribal habits.....	378
9.1.5	Deterministic approach.....	379
9.1.6	Probabilistic approach.....	380

9.1.7	Estimating probabilities.....	381
9.1.8	Survival of the fittest.....	382
9.1.9	The fittest feature and textual development.....	386
9.2	Dissemination of manuscripts.....	387
9.2.1	Production.....	388
9.2.2	Transport.....	410
9.2.3	Survival.....	411
9.2.4	Recovery.....	414
9.3	Computer simulation of textual development.....	415
9.3.1	Book production.....	416
9.3.2	Transport.....	418
9.3.3	Survival.....	421
9.3.4	Recovery.....	422
9.3.5	Copying.....	424
9.3.6	Correction.....	428
9.3.7	Some useful aspects of simulation.....	431
9.4	Possible outcomes of simulation.....	432
9.4.1	Geographically specific texts.....	432
9.4.2	Drift and temporally specific texts.....	432
9.4.3	Extinction.....	433
9.4.4	Analogies with population biology.....	434
10	CONCLUSION.....	449

APPENDICES

A1	TRANSCRIPTION NOTES.....	458
A1.1	P12.....	463
A1.2	P13.....	465
A1.3	P17.....	475
A1.4	P46.....	477
A1.5	P79.....	510
A1.6	P89.....	512
A1.7	U1.....	514
A1.8	U1s.....	537
A1.9	U2.....	540
A1.10	U3.....	550
A1.11	U4.....	578
A1.12	U6.....	603
A1.13	U15.....	676
A1.14	U16.....	686
A1.15	U18.....	690
A1.16	U20.....	701
A1.17	U25.....	712
A1.18	U44.....	718
A1.19	U48.....	724
A1.20	U56.....	728
A1.21	U75.....	733
A1.22	U75s.....	743
A1.23	U122.....	746
A1.24	U142.....	750
A1.25	U150.....	760
A1.26	U151.....	767
A1.27	U227.....	774
A1.28	U228.....	776
A1.29	U243.....	779
A1.30	U252.....	781
A1.31	M2815.....	783
A2	SUPPLEMENTARY TEXTS.....	786
A3	BASIS FOR CRITERIA DATA.....	798
A3.1	Heb 1.3.....	800
A3.2	Heb 1.8.....	802
A3.3	Heb 1.12a.....	804
A3.4	Heb 1.12b.....	804
A3.5	Heb 2.7.....	805
A3.6	Heb 2.8.....	806
A3.7	Heb 2.9.....	807
A3.8	Heb 3.2.....	811
A3.9	Heb 3.6a.....	812
A3.10	Heb 3.6b.....	814
A3.11	Heb 4.2.....	814
A3.12	Heb 4.3a.....	817
A3.13	Heb 4.3b.....	818
A3.14	Heb 6.2.....	818
A3.15	Heb 6.3.....	822
A3.16	Heb 7.21.....	822
A3.17	Heb 8.8.....	823
A3.18	Heb 8.11.....	825
A3.19	Heb 9.1.....	826
A3.20	Heb 9.10.....	827

A3.21	Heb 9.11.....	828
A3.22	Heb 9.14a.....	829
A3.23	Heb 9.14b.....	830
A3.24	Heb 9.17.....	830
A3.25	Heb 9.19.....	832
A3.26	Heb 10.1a.....	834
A3.27	Heb 10.1b.....	835
A3.28	Heb 10.11.....	836
A3.29	Heb 10.34a.....	837
A3.30	Heb 10.34b.....	838
A3.31	Heb 10.38.....	839
A3.32	Heb 11.1.....	840
A3.33	Heb 11.11.....	840
A3.34	Heb 11.23.....	841
A3.35	Heb 11.37.....	843
A3.36	Heb 12.1.....	845
A3.37	Heb 12.3.....	847
A3.38	Heb 12.18.....	849
A3.39	Heb 13.15.....	850
A3.40	Heb 13.21a.....	852
A3.41	Heb 13.21b.....	853
A3.42	Heb 13.21c.....	853
A3.43	Heb 13.25.....	855
A4	SUMMARY OF CRITERIA DATA.....	860
A5	EQUIVALENTS NOTES.....	865
A5.1	Introduction.....	865
A5.2	Notes.....	873
A6	MAP NOTES.....	959
A6.1	Identical maps.....	959
A6.1.1	Identical textual maps.....	959
A6.1.2	Identical spelling maps.....	959
A6.2	Unmapped witnesses.....	960
A6.2.1	Unmapped textual witnesses.....	960
A6.2.2	Unmapped spelling witnesses.....	960
A7	MAPS.....	
A7.1	Textual maps.....	962
A7.2	Spelling maps.....	1117
A7.3	Other maps.....	1188
A8	PROGRAM LISTINGS.....	1195
A8.1	Preprocessing program.....	1196
A8.1.1	prep.....	1196
A8.2	Collation programs.....	1206
A8.2.1	Filter.....	1206
A8.2.2	Separate.....	1210
A8.2.3	Format.....	1215
A8.2.4	Normalise.....	1223
A8.2.5	Synthesise.....	1230
A8.2.6	Matrix.....	1236
A8.2.7	Report.....	1247
A8.3	Utility programs.....	1254
A8.3.1	Check.....	1254
A8.3.2	Punctuation.....	1257
A8.3.3	Tabulate.....	1260

A8.3.4	LSI.....	1263
A8.3.5	CT.....	1266
A8.3.6	Halve.....	1272
A8.3.7	LI.....	1273
A9	DATA	
A9.1	Disk 1.....	Disk 1
A9.1.1	Transcriptions	
A9.1.2	Supplementary	
A9.2	Disk 2.....	Disk 2
A9.2.1	Equivalents	
A9.2.2	Unwanted	
A9.3	Disk 3.....	Disk 3
A9.3.1	Preprocess	
A9.3.2	Collation	
A9.3.3	Utilities	
A9.4	Disk 4.....	Disk 4
A9.4.1	MacPerl	
A10	BIBLIOGRAPHY.....	1279

ACKNOWLEDGMENTS

Many have contributed to this thesis. My beautiful wife, Eliane, has been a wonderful companion and has put up with my doleful demeanour during times of trial. Her love, prayers, and encouragement have contributed in no small way. My parents, Dorothy and John, have been a constant help throughout, providing much practical support and love. Dorothy proof-read the entire thesis as well. My friends and family have made a big difference, listening with feigned interest as I rambled on about manuscripts, and praying for a quick end to it all.

I am convinced that if it were not for my long-suffering supervisor, Dr Richard K. Moore, this work would never have been finished. He is a scholar and mentor of the highest calibre. As a result of his guidance, many rough edges have been smoothed, not to mention some glaring errors. In particular, I am grateful for his help with sticky questions of Greek grammar that surfaced during the course of research. A New Testament specialist should not have to be subjected to the rigours of computer programming, statistics, and multivariate analysis. Yet Dr Moore was able to keep track of my wanderings and to bring me back to straight paths when I had gone astray. I have appreciated his quiet encouragement and prayers as well. On the subject of supervision, Dr Bill Loader kindly agreed to act as my supervisor for a period of six months while Dr Moore was on leave.

The Baptist Theological College of Western Australia provided me with my theological education, a well-stocked library in which to study, and ongoing support in the form of a place to study. I give my thanks to the Principal, Dr John Olley, and to the office staff, Thelma Burton and Nerissa Prangnell. Thelma often helped me with practicalities such as printing and copying. The librarians Val Wild and Lynn White, along with their helpers, John Bardwell-Dix, Don Clow, and others, have provided services of the highest quality. Val and Lynn were always willing to help, and were a great encouragement as well.

My university has made significant contributions. Besides generous grants that enabled me to study manuscripts in England, Germany, and Greece, and to attend conferences in Norway and England, the Murdoch

University librarians helped to track down many obscure references through the Inter-library Loans Service.

During the overseas trips, I was granted many courtesies at the British Museum's manuscript reading room and the Athens National Library. The Institute for New Testament Textual Research in MŸnster, Germany, generously provided me with a room in which to examine their magnificent microfilm collection over a period of two months. I found a one-hour lunch-time discussion with the researchers there as useful as a month's study of books. It was with great sadness that I heard of Prof. Kurt Aland's death. I have fond memories of a short conversation with him in which his cigar smoke filled the room and his insightful comments filled my head. Prof. Barbara Aland continues to head the good work of the Institute. I enjoyed my time there immensely, not least because of the friendliness and hospitality of people such as Michael Welte and his family, Klaus Wachtel, Holger Strutwolf, and Nektarios Papadopoulos. Nektarios took me out for meals on numerous occasions, and made up for my ignorance by happily translating between Greek, German, and English. There were others at the Institute who made my stay enjoyable, and I apologise for not mentioning all of them specifically.

A number of institutions supplied the microfilms, Xerox copies, and photographs from which most of my transcriptions were made. Among these are the Ancient Biblical Manuscript Center in California, The Monastery of Saint John on Patmos, the Austrian National Library, and the Russian National Library.

Many individuals deserve special mention, but I will have to be content with naming a few. Robert Kraft told me about the work of Peter Robinson. Dr Robinson's *Collate* program served as a conceptual springboard for many of my programs, and his transcription method was vital to the success of my research. Jan—s Podani wrote the multivariate analysis package that has played such an essential part in my analysis. I thank Kristina Lemson, who informed me that such a package existed. James K. Tauber made two important contributions. Firstly, he suggested that I should use the PERL programming language. He also contributed to the idea of creating a data matrix of readings from the critical

apparatus of the UBS4 Greek New Testament. Ron Felton and John Dawson made valiant attempts to explain multivariate analysis to me when I knew nothing about it. Geoffrey Farthing got me thinking along the lines of applying probability theory to questions of textual variation. Shelly Harrison, of the University of Western Australia, helped me with a number of linguistic definitions.

Computers and communication via computers have played a large part in my research. I am indebted to those many people who made computers accessible to ordinary people, especially to those who developed Macintosh computers. The Internet has greatly facilitated communication across the great distances that separate my homeland from every other place. A number of people from the textual criticism discussion list, *TC*, have made useful suggestions that have contributed to this work. Among these are Jimmy Adair, Bob Waltz, Maurice Robinson, Jim West, and Ulrich Schmid.

There are a few others I would like to single out. One is Adrie Devitt, who worked hard to translate an important paper by Gerd Mink from German, then refused payment for the task. Another is Christina Lemke, who, in 1993, suggested that I ask for an image of a New Testament papyrus to be made, using a digital camera. Andrew Prescott of the British Library's manuscript reading room kindly made an image of a few letters of P13 for me, with the approval of the Keeper of Manuscripts, T. S. Pattie. This may have been the first time that a digital camera was used to make an image of a New Testament manuscript.

Someone once said that we stand on the shoulders of giants. This is a most appropriate maxim in the field of New Testament textual research. Those who have gone before us have made a strong foundation on which to build. My appreciation for the efforts of past scholars grew as my research progressed.

Above all, I acknowledge the help of Jesus Christ. When I look back, I see the evidence of divine guidance that has taken this research into places that I would not have dreamed of entering. There were many times when I had reached the end of my abilities and could go no further. At those times I prayed for help, and help was forthcoming. It is therefore

fitting that I should dedicate this work to the one whose greatness the writer to the Hebrews did so well to praise.

DEDICATED TO JESUS CHRIST

Son of God,
Mediator of the New Testament,
Apostle and High Priest of our profession,
able to save to the uttermost those that by him come to God.

ABBREVIATIONS

General

CE	common era (replaces the older AD, or <i>anno Domini</i>)
Heb	epistle to the Hebrews
LXX	Septuagint
MS	manuscript
NT	New Testament
cf.	<i>confer</i> , compare
e.g.	<i>exempli gratia</i> , for instance
i.e.	<i>id est</i> , that is
fig.	figure
n.	note
~	about, approximately equal to

Editions

- BAGD Bauer, Walter. 1979. *A Greek-English lexicon of the New Testament and other early Christian literature*. Trans. William F. Arndt and F. Wilbur Gingrich. 2nd rev. and augmented ed. Ed. F. Wilbur Gingrich and Frederick W. Danker. Chicago: University of Chicago Press.
- BDF Blass, Friedrich and Albert Debrunner. 1961. *A Greek grammar of the New Testament and other early Christian literature: a translation and revision of the ninth-tenth edition incorporating supplementary notes of A. Debrunner*. Trans. and ed. Robert W. Funk. Chicago: University of Chicago Press.
- NA26 Aland, Kurt, Matthew Black, Carlo M. Martini, Bruce M. Metzger, and Allen Wikgren (eds.). 1979. *Novum Testamentum Graece*. Nestle-Aland, 26th ed. Stuttgart. Deutsche Bibelgesellschaft.
- NA27 Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo

M. Martini, and Bruce M. Metzger (eds.). 1993. *Novum Testamentum Graece*. Nestle-Aland, 27th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.

UBS3 Aland, Kurt, Matthew Black, Carlo M. Martini, Bruce M. Metzger, and Allen Wikgren (eds.). 1983. *The Greek New Testament*. United Bible Societies, 3rd corr. ed. New York: United Bible Societies.

UBS4 Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.

T8 Tischendorf, Konstantin von (ed.). 1872. *Novum Testamentum Graece*. Vol. 2. 8th major critical ed. Leipzig: Giesecke and Devrient. Repr. 1965. Graz: Akademischen Druck.

TR *Η ΚΑΙΝΗ ΔΙΑΦΗΚΗ*. 1873. Fascicle 7. Oxford: Oxford University Press. Repr. n.d. Chicago: University of Chicago Press. (This is essentially the same text as Stephanus' 3rd ed. of 1550, the text which became known as the *Textus Receptus*.)

Bibliographical

corr.	corrected
ed.	editor, edition, edited by
intro.	introduction
n.d.	date not known
n.p.	publisher not known
n.pl.	place not known
repr.	reprinted
rev.	revised
trans.	translated, translated by
vol.	volume

f.	folio
r.	recto

v. verso

INTRODUCTION

The objective of this study

The field of New Testament textual research has long been frustrated by an inability to make comprehensive use of its manuscript riches. Critical editions employ ingenious devices to squeeze copious information into the available space, yet much that is useful must still be omitted. These economies are made necessary by the constraints of the printed page.

The advent of computers has set us free from bonds of this kind. Indeed, it would be possible to store a letter-for-letter transcription of every Greek New Testament manuscript in a few CD-ROMs, provided these transcriptions were available. In other words, a comprehensive thesaurus of Greek New Testament manuscript texts is achievable with the current generation of personal computers. Such a thesaurus would still only have a limited area in which to display its texts. Strategies for simultaneously displaying the many extant texts in a compact yet comprehensible way therefore need to be developed.

The immense processing power of today's computers could be used to achieve this and other goals: transcriptions could be grouped according to their textual or spelling characteristics, searches could be performed over any sub-group, and specialist programs could be applied to find a probable genealogical structure that conforms to the available evidence. These are just a few of the potential applications of a computer-based tool for the analysis of manuscript texts. The objective of this study is to take a few steps towards realising this potential.

Arrangement

Apart from the introduction and conclusion, each chapter of this thesis is provided with a synopsis that alerts the reader to the chapter's contents, and a summary that draws together important features of the ground that has been covered.

Following the thesis are appendices that include basic data such as transcriptions, documentation supporting the basic data, and results of

the analysis in the form of classical scaling maps. The appendix entitled *Equivalents notes* is concerned with differentiating textual and spelling variations. It makes frequent references to the first appendix, which contains transcription notes. For the reader's convenience, these two appendices have been placed in separate volumes. In this way, both volumes can be left open to the appropriate places during cross-referencing.

Separate reference lists are provided for each chapter and for each manuscript treated in the transcription notes. A comprehensive bibliography is also given at the end of the appendices. Tables and maps are placed under the general heading of 'figures' and relegated to the ends of chapters, thereby avoiding large blank sections at the ends of some pages.

Nomenclature

This study ranges across a number of disciplines including palaeography, Koine Greek grammar, computer programming, multivariate analysis, and history. As a general rule, I have attempted to use recognised nomenclature in a consistent manner. Due to the pioneering nature of this research, I sometimes found it necessary to develop my own nomenclature. Such descriptive terms as 'supplementary witness', 'principal data matrix', and 'sample data matrix' are my own constructions. I hope that these will serve to avoid confusion, but I do not expect them to become standard. I am beset by an uneasy feeling that many of these terms could be improved, and I would be the first to welcome a more consistent and natural terminology.

I am guilty of one presumptuous innovation. Rather than employing the 'O' prefix used in the Gregory-Aland designation of Greek uncial manuscripts, I use the letter 'U'. This results in a simple system that can be applied across the various manuscript categories, allowing the use of a plain 'P' for papyri, 'U' for uncials, 'M' for minuscules, and 'L' for lectionaries. This scheme has positive advantages when it comes to mapping exercises where the initial 'O' might be confused with a Gregory-Aland number, and situations in which special fonts cannot be used. It may be preferable to use the term 'majuscule' instead of 'uncial'

to describe parchment manuscripts written with capital letters (see Turner, 1987, 1). However, to do so would result in confusion between minuscules and majuscules when using my simplified designations. Besides, it is common practice for New Testament textual researchers to describe parchment manuscripts written with capital letters as uncials. I continue this practice here.

During the course of research, I found it necessary to find a general term that could be applied to any place of variation. 'Variation unit' is not suitable as it is commonly understood to apply to textual variations rather than all kinds of variations. Whereas I use the simple term 'unit' for this purpose, I would like to see a more specialised term adopted. This would avoid the potential for confusion that can presently occur through reading a sentence such as, 'The map is based on data from 728 units and spans 0.8 units along the first axis.'

Another word of this kind is 'feature', that I use to describe a particular instance of variation. In this context, a feature can be a phrase, a word spelled in a particular way, a certain way of abbreviating or contracting a word, a punctuation mark, or a place where a new line of text begins. Once again, a more specialised term would be preferable to avoid confusion.

Variations can relate to text, spelling, punctuation, compendia, abbreviations, contractions, line-divisions, page-divisions, and so on. The general terms 'textual', and 'spelling' are appropriate to variations in text and spelling. No single term exists to cover all of the other kinds of variation, so I have been driven to adopt the highly unsatisfactory term 'other' for the purpose. Perhaps 'peripheral' would be better, although there is nothing peripheral about these kinds of variation.

Another cause for concern is my labelling of scribes and correctors. I have used the numeral '0' to refer to the original scribe of a manuscript, '1' for first corrector, '2' for the second corrector, and so on. It may be better to use '1' for first hand (i.e., original scribe), '2' for second hand (i.e., the first corrector), and so on. If it were thought wise to implement such a change, all of my transcriptions of corrected manuscripts would have to be *carefully* changed. The same goes for the programs I have

written to separate transcriptions into the work of consecutive scribes.

A siglum such as P46-1 may refer to the text written by a scribe or to the scribe as an individual. As a result, different relative pronouns such as 'who' or 'which' are used in conjunction with the sigla, depending on the context.

Terms such as 'Alexandrian', 'Caesarean', 'Western', and 'Byzantine' are all understood to be provisional and possibly inappropriate descriptions of texts that share certain affiliations. Where these terms are used, they are not enclosed in quotation marks.

To conclude this section on nomenclature, a particular inconsistency needs to be highlighted. At first, I decided to signify the scribe who copied the supplementary folio of Hebrews in Codex Sinaiticus as U1-1. During the programming phase, I realised that it was unwise to treat this scribe as a corrector and that a better approach was to treat the relevant section of text as a separate unit, designated U1s. Therefore, the reader may search for the siglum U1-1, but it will not be found because U1-1 has been replaced by the siglum U1s. In the same way, U75s is used in place of what was labelled U75-1 at first. As a consequence, the first correctors of U1, and U75 are U1-2 and U75-2, respectively. This is a regrettable inconsistency that I would like to have corrected, given more time.

Notes and references

In an attempt to make this work easier to read and more aesthetically pleasing, I have adopted some possibly unusual conventions. Footnotes have been avoided throughout. Instead, matter that is not directly relevant to the development of a discussion is marked with round brackets. References are marked in the same way, using the 'author-date' system. More extended quotations have been placed in separate blocks, with those of less than three or four lines being incorporated in the text and marked by single quotation marks. Where a quotation begins with a capital letter but the context requires a lower case letter, the capital has been retained instead of replacing it with a lower case letter in square brackets. Lawrence D. McIntosh's *A style manual for the presentation of*

papers and theses in religion and theology has proven to be an invaluable guide in all aspects of referencing, bibliography, and thesis presentation in general.

Scribes

If it had not been for the scribes who copied the New Testament, there would be no need for a study of this kind. There would be no variation among manuscripts because there would be no manuscripts at all. We owe a great deal to the copyists. It is all too common to describe them as lazy, careless, ignorant, and blundering. I beg to differ. On a number of occasions, I have conducted experiments in which a class of university students is given the task of copying a few verses from an English version of the New Testament. It is amazing how error-prone these modern copyists are, by comparison. I have developed a healthy respect for the ancient scribes, who copied with a far lower error-rate.

It may seem that I am guilty of such disparagement as well. Later in the thesis, I use Zipf's principle of least effort as a basis for understanding certain scribal behaviours. This does not mean to say that I regard scribes as lazy. Instead, it means that they were like the rest of us, taking the course of least resistance where possible. According to this view, it would be more appropriate to describe copyists as efficient rather than lazy. I will be glad if my efforts to make the New Testament textual tradition more widely accessible prove worthy of their respect.

References

- McIntosh, Lawrence D. 1995. *A style manual for the presentation of papers and theses in religion and theology*. Corrected ed. Wagga Wagga: Centre for Information Studies.
- Turner, E. G. 1987. *Greek manuscripts of the ancient world*. Institute of Classical Studies bulletin supplement, 46. 2nd rev. and enlarged ed. Ed. P. J. Parsons. London: Institute of Classical Studies.

SOURCES

Synopsis

The text of the epistle to the Hebrews rests primarily upon direct manuscript testimony. While all documentary sources are important, not all of them have an equal bearing on the primitive text. In addition, practical considerations make it necessary to restrict the number of manuscripts subjected to detailed analysis. For the purposes of this study, the transition from uncial to minuscule writing has been chosen as a boundary, reducing the number of Greek manuscripts requiring complete transcription to thirty.

This is a poor strategy if it results in other important classes of evidence being ignored. In order to avoid such an oversight, texts of significant minuscule, lectionary, patristic, and versional witnesses have been sampled by reference to editions, including UBS4. The variation units of this edition also act as a framework in which to sample texts that conform to the preferences of selected editors, authors, and critical principles. All of these sampled texts provide a contextual setting in which to consider the complete transcriptions.

This chapter identifies the authoritative sources from which these complete and sampled texts are compiled.

Primary witnesses

As a consequence of the progressive triumph of the minuscule script from the ninth century onwards, all papyrus and nearly all uncial Greek New Testament manuscripts were written in the first millennium CE. As they represent the most ancient class of evidence, the accessible New Testament papyri and uncials comprise the primary witnesses for the text of the epistle to the Hebrews to be considered in this study.

Identification

Most of these manuscripts are identified by consulting Appendix 1 of NA27. Some manuscripts which are regarded as of little consequence for establishing the text (such as U56) are not included there. A more complete listing is found in the Alands' *Text of the New Testament* (1989) which includes papyri up to P96, uncials up to U299, and summaries of their contents (except for U278 to U296). These summaries are often in the 'eapr' form, where 'e' = Gospels, 'a' = Apostolos (i.e., Acts and catholic epistles), 'p' = Pauline epistles (under which Hebrews is listed), and 'r' = Revelation. Kurt Aland's *Kurzgefasste Liste* (1994) is even more comprehensive, and is the most convenient source for this information.

A careful examination of these references yields the following catalogue of papyrus and uncial manuscripts that cover Hebrews: P12, P13, P17, P46, P79, P89, U1, U2, U3, U4, U6, U15, U18, U20, U25, U44, U48, U56, U75, U122, U142, U150, U151, U227, U228, U243, U252, U278, U280, and U285. The process by which this list was compiled was not as straightforward as this summary indicates. Some manuscripts were only added as a result of information obtained at the Institute for New Testament Textual Research in M nster, Germany.

Access

As a rule, it is difficult to gain direct access to manuscripts of the New Testament. They are located in diverse places and are closely guarded. Should travel to a manuscript's repository be possible, a reader's pass is normally required before viewing is allowed. Due to the wide dispersion of these manuscripts, most researchers are obliged to employ indirect means to examine them.

Among substitutes for the manuscripts themselves are high definition digital images, colour transparencies, facsimile editions, 35 mm photographs or microfilms, and Xerox prints of microfilms. Colour is preferable to black and white because it facilitates differentiation between scribes and correctors. Recently, advanced techniques such as multi-spectral imaging have been applied to certain manuscripts, revealing details invisible to the naked eye (Bearman and Spiro, 1996, 56-66). What is more, computer processing of multi-spectral images should allow different inks to be distinguished. Consequently, a researcher would be able to differentiate between scribes in a more objective fashion than is currently possible. Regrettably, the more technologically advanced an imaging system is, the more expensive it tends to be.

Until now, economic constraints have forced researchers to use black and white microfilms or Xerox prints of these, although colour facsimile editions are occasionally available. The availability of higher quality images would be of great benefit to the field, especially in relation to poorly preserved, extensively corrected, or palimpsest manuscripts. The World-Wide Web communication network would be a suitable means of conveying such images to scholars.

These points may be illustrated by reference to P13, which I had the good fortune to study at the British Library. When looking at the original, I was in little doubt as to what was papyrus, ink, stain, shadow, or reflection from the glass cover. Part of this manuscript was once held in Florence, but has now been repatriated to Cairo. The only image of this fragment that I have been able to see was a poorly focused, black and white photograph that seemed to have been taken at an oblique angle. After prolonged scrutiny, all kinds of imaginary letters seemed to appear. Researchers are constrained to using poor images of this kind too often, and transcriptions suffer as a result.

Photographic collections

Nevertheless, the compilation of photographic collections during this century has enabled a great advance in the field. While the least preferable in terms of image quality, photographs are often the first

choice because of their wide coverage, relatively low cost, and accessibility.

The foremost collection is the result of the life's work of Professor Kurt Aland. This work is now carried on by Professor Barbara Aland and the researchers at the Institute for New Testament Textual Research in Münster, Germany. Virtually every New Testament manuscript can be seen in microfilm, photographs, or facsimile editions held at the Institute. The research underlying this thesis has been greatly helped by two visits there. Not only are the resources second to none, but one cannot help learning a great deal from the researchers. Unfortunately, the Institute is not generally able to supply resources to those who cannot travel there. In some cases, constraints are placed on distribution of material due to agreements that had to be made in order to secure images from the custodians.

The Ancient Biblical Manuscript Center (ABMC) in Claremont, California, is another valuable source for those seeking films of New Testament manuscripts. It has a large number of microfilms, photographs, and facsimile editions of biblical manuscripts available for loan. These are listed in a catalogue published by the Center (Lundberg, 1992). Once it has been established that the collection includes a required item, films may be requested from the following address through Inter-library Loans:

Ancient Biblical Manuscript Center
PO Box 670
Claremont CA 91711
USA

The ABMC holds images of a substantial number of the required manuscripts: photographs of U48 (a palimpsest) from the J. Harold Greenlee Collection, a film copy of Kirsopp Lake's photographic facsimile of U1, films of U2, U3, U4 (a palimpsest), U15, U44, U75, U122, U142, and U243 (formerly U121b) from the International Greek New Testament Project collection, films of U150 and U151 from the collection of Patmos manuscripts on loan from the Institute for Antiquity and Christianity, a film of U6 from the collection owned by the

Claremont School of Theology Library, facsimile editions of P46, U1, U2, and films of P13, P17, P79, U1, U3, U4, U6, another part of U15, U20, U25 (a palimpsest), U48, U56, U227, and U228 from the ABMC holdings. This survey shows the great value of the Center: facsimiles of nineteen or twenty of the thirty required manuscripts are held there. Unfortunately, some of these resources cannot be borrowed through Inter-library Loans. The range available to students who cannot travel to the Center is therefore somewhat restricted.

A condition of loan is that microfilm copies may not be made. The transcription process usually takes longer than the loan time, and images nearly always need to be consulted again at later stages. Hard copies, in the form of Xerox prints produced with a microfilm printing machine, must therefore be made. The resultant prints have the appearance of photocopies. As some definition is lost through the printing process, the copies are only useful if the original manuscript is in fairly good condition. With regard to being able to see the underlying text of palimpsests, Xerox prints of microfilms range from barely adequate (e.g., U4) to completely useless (e.g., U25).

Other resources

If the original is poorly preserved, is a palimpsest, or has been corrected by a number of scribes, it is important to obtain better images, or to supplement the information provided by low definition images in some other way. Ultra-violet photographs are useful for revealing washed away, obliterated, and faded text. If better images are difficult to obtain, perhaps because they have not been made or because they are too expensive (e.g., US\$700 for ultraviolet photographs of U4), recourse may be made to editions by those who have worked from high quality images or the manuscript itself. J. Keith Elliott's *A bibliography of Greek New Testament manuscripts* is useful in tracking down such editions.

Konstantin von Tischendorf's works are frequently mentioned in Elliott's reference work. Tischendorf produced diplomatic editions of many of the uncials. His notes include invaluable information about corrections, the only drawback being that they are written in Latin. He also left us a pseudo-facsimile of Codex Sinaiticus and his eighth major critical edition, which is yet to be surpassed in certain regards. On a number of

occasions, I have had to correct my transcriptions after taking the time to translate his notes.

Where the student is constrained to work with low quality images of a problematic manuscript, constant reference to a reputable edition serves to make the transcription more robust. This is true of palimpsests and often-corrected manuscripts for which the underlying text is indiscernible in microfilm prints. For such manuscripts, it is often necessary to rely entirely on the editions in order to make useful transcriptions.

Here is another area where the availability of high definition digital images would be of great benefit. In addition, the new multi-spectral imaging technology could be applied to palimpsests such as Codex Ephraemi Syri Rescriptus (U4). (Tischendorf managed to transcribe this manuscript, to the amazement of everyone who had seen it.) Software tools could be used to filter out the superimposed text, and *voila*: the original text would be restored to us many centuries after being washed off to make way for Ephraem's sermons.

Returning to the list of required manuscripts, sources for P12, P46, P89, U18, U150, U151, U252, U278, U280, U285, and parts of U15 remain to be found. Once again, J. Keith Elliott's *Bibliography* proves useful. It lists references containing transcriptions and plates of many of the papyri and uncials, and shows that a plate of P12 is available in Grenfell and Hunt's *The Amherst papyri*, plates of P46 are available in Kenyon's *The Chester Beatty biblical Papyri*, and that a plate of U252 is found in the journal *Helmantica*.

It is important to realise that if Elliott lists a reference as containing plates of a particular manuscript, this does not imply that the whole manuscript is covered. In fact, the references only include plates of one or two sheets in most cases. In this case, however, plates of all of P12, P46 and U252 are found in the given references. The list has now been reduced to U18, U150, U151, U278, U280, U285, and parts of U15. With all other avenues exhausted, requests for photographs or film copies of the manuscripts must be made to the custodians themselves.

Whereas NA27 and Aland's *Kurzgefasste Liste* (1994) are useful for obtaining manuscript locations, they do not give full addresses for the custodians. If the custodian is a university, college or library, its address can often be found in a reference such as the *World of learning*. If this fails, the local consulate of the custodian country might be of assistance. Where the manuscripts are held in a monastery, a representative of the relevant church may be able to supply an address. Recourse may also be made to an Internet discussion list such as *papy* (papy@igl.ku.dk). The Institute for New Testament Textual Research in MŸnster is always helpful, but should only be approached when the student has exhausted other avenues.

In this manner, the list was reduced to U18, U278, U280, U285, and parts of U15. Replying to a request for photos of one part of U15, the custodian wrote back to say that it was impossible to make a copy because of the state of the manuscript. Fortunately, Murdoch University provided a grant which made it possible for me to visit the Institute in MŸnster. While there, I was able to transcribe U18, and the previously unobtainable parts of U15. At the same time, I was able to consult many of the works mentioned in Elliott's *Bibliography*. These are sometimes too old or rare to be obtained through Inter-library Loans.

At the end of my searches, U278, U280, and U285 remained inaccessible. These manuscripts are from the 1975 find at Saint Catherine's monastery in the Sinai. They would have contributed to the present study, especially with respect to the orthographical analysis. Unfortunately, I was not able to examine photographs of them at the Institute in MŸnster because of conditions imposed on their availability by the custodians. This situation is reminiscent of that which prevailed for the Dead Sea Scrolls. Hopefully, full editions will soon be published to make their texts available.

Supplementary witnesses

While my thesis places emphasis on the earliest Greek manuscript evidence, its conclusions would be weaker if other important sources of documentary evidence were neglected. Besides preserving ancient forms of the text, these supplementary witnesses have the potential to add

temporal and geographical dimensions to the data. In other words, they may help to shape a map that traces the textual development of the Greek New Testament.

The editors of UBS4 have provided a selective apparatus of variation units for certain papyrus, uncial, minuscule, lectionary, patristic, and versional manuscript evidence. The UBS4 introduction outlines the method by which these witnesses were chosen (1993, 3*-4*):

The purpose of selecting witnesses for the critical apparatus was generally to provide a broad number of witnesses that would be significant and representative of the whole tradition for the limited number of instances noted in the apparatus in this edition. The emphasis is therefore naturally on Greek manuscripts of the New Testament. The result was a completely new selection, based on verifiable tests of the entire Greek manuscript tradition in the Institute for New Testament Textual Research at Münster. The criterion for acceptance of evidence from the versions and Church Fathers was the availability of all reliable evidence for their New Testament text on the basis of current scholarly research.

The emphasis on significant and carefully vetted evidence makes this apparatus a suitable source of minuscule, lectionary, patristic, and versional evidence. Its variation units also provide a convenient framework by which a sample of supplementary evidence can be incorporated into my analysis. The disadvantage of the sampling approach is that its results represent mere approximations to the true values that would be obtained with complete evidence.

A law of diminishing returns operates when sampling large populations. At first, conclusions drawn from samples quickly improve in accuracy as the sample size increases. Accuracy often reaches a tolerable level at fairly small sample sizes. Larger samples give better accuracy, but not in a linear fashion, so doubling the sample size will give less than a two-fold improvement in accuracy. Hence, it is reasonable to seek the minimum sample size which will give the desired level of accuracy.

In the present case, the population consists of all variation units in the epistle to the Hebrews. The minimum sample is the smallest set of units

that will give an adequate estimate of actual values. The minimum sample size is difficult to estimate because textual data are qualitative and not quantitative; that is, they are nominal and not numerical. It is therefore necessary to choose a convenient sample under the assumption that it is large enough to adequately represent true values. It is in this context that the forty-four variation units of the UBS4 apparatus of Hebrews have been chosen.

Uncials

As mentioned before, U278, U280, and U285 could not be obtained for transcription. The texts of two of these, U278 and U285, have been reconstructed from the apparatus of Wachtel and Witte (1994). As U280 is not cited in this volume, its text could not be reconstructed.

Minuscules

Minuscules contribute to a knowledge of manuscript relationships and bear witness to the evolutionary forces that acted upon the text:

É they allow one to draw lines of development that reach into the early period and that help to clarify how the solitary representatives of the earlier tradition [i.e., the papyri and uncials] are related to one another. By means of such genealogies, it is possible to determine the ways that NT MSS vary from one another, to understand why these variations came into being, and to study the persistence of particular readings and forms of the text in the tradition (Aland and Wachtel, 1995, 47).

In addition, some minuscules, such as M33 and M1739, preserve texts that resemble those of much older papyrus and uncial manuscripts.

The previous extract from the introduction to UBS4 (1993, 3*) says that the witnesses included in its apparatus are intended to be 'significant and representative of the whole tradition'. They have been chosen on the basis of research conducted at the Institute for New Testament Textual Research, which has resulted in the isolation of important minuscules. Thus, the minuscule component of the selection can be expected to provide a useful sample of this significant class of witnesses.

Lectionaries

Greek lectionary evidence has often been ignored because of the common perception that it is a later development which has no bearing on the early text. This may not be a safe assumption because, like the minuscules, the lectionaries provide insight into the dynamics of the early text:

Evidence from the Greek lectionaries is vital in tracing the history of the transmission of the text of the NT, and as various readings in the MS tradition owe their origin to the influence of the lectionaries, these neglected witnesses are important in determining the original text of the NT (Osburn, 1995, 61).

Lectionary evidence may even go further to provide direct evidence for the early text:

Inasmuch as the form of the citation of the Scriptures in official liturgical books always tends to be conservative and almost archaic, lectionaries are valuable in preserving a type of text that is frequently much older than the actual age of the manuscript might lead one to suspect (Metzger, 1992, 31).

The search for early texts should, however, be restricted to the few early, non-Byzantine lectionaries. This is because the Byzantine lectionary system probably did not emerge until the seventh century (Aland and Aland, 1989, 168).

According to the UBS4 (1993, 19*) introduction, a new selection and collation of its lectionary evidence has been undertaken. Care has also been taken to include those lectionary manuscripts which do not conform to the normal Byzantine standard. As a result, this selection should provide an adequate basis for the incorporation of lectionary evidence. The relative neglect of this type of evidence calls for its consideration in a broadly based comparison of witnesses. Unfortunately, lectionaries do not figure in the results of this thesis. This is because the number of variation units that cover individual lectionaries in the UBS4 apparatus of Hebrews is too small to allow subsequent analysis.

Patristic citations

Patristic evidence has special value for a study which aims to map the New Testament text's early development. In his editorial introduction to the Society For Biblical Literature's *New Testament in the Greek Fathers* series, Gordon D. Fee wrote:

when a Father's text can be judged as certain (e.g. when he provides a commentary on the very words of his text or notes alternative readings), it provides datable primary evidence for the New Testament text in a given geographical location (in Ehrman, 1986, xi).

There is good reason not to trust the patristic citations found in many modern editions because little care has been taken to address the uncertainties that beset them. The editors of UBS4 were sensitive to these problems, and described their way of addressing them in the following terms (1993, 29*-30*):

The whole field of New Testament citations in the Church Fathers has been thoroughly reviewed. For a citation to be included there were two criteria to be met. The citation must be capable of verification, i.e., the New Testament text or the manuscript cited by the author must be identifiable. Patristic paraphrases, variations, and allusions have no place in this edition. In contrast to earlier editions, emphasis has been placed on offering as complete a survey as possible of the Fathers through the mid-fifth century, because the citations of these authors are of the greatest importance for reconstructing the original text of the New Testament.

The justifiably stringent requirements of the UBS4 editors has resulted in the number of patristic citations being reduced by comparison with UBS3. This reduction would have the effect of excluding many Church Fathers from inclusion in subsequent stages of my analysis unless the number of citations were increased in some way. For this reason, I have supplemented the UBS4 citations with data taken from Tischendorf (1872), Souter (1947), Zuntz (1953), and UBS3 (1983). The increased number of citations is necessarily accompanied by a reduction in the quality of the patristic data relative to the standards of UBS4. Citations for two Church Fathers have been compiled from volumes in the *New Testament in the Greek Fathers* series: James A. Brooks' *The New Testament text of Gregory of Nyssa* (1991), and Roderic L. Mullen's *The*

New Testament text of Cyril of Jerusalem (1997).

Versions

The versions provide implicit evidence of the ancient Greek texts from which they were translated. They also have locational value, although not generally with a precision equal to patristic evidence. The UBS4 apparatus provides an appropriate source of versional evidence for the present purposes because it only includes citations that are virtually certain (1993, 22*): 'the versions are cited only in instances where their underlying Greek text may be determined with certainty or with a high degree of probability.' Only those versions are included which are most likely to have been translated directly from the Greek text (UBS4, 1993, 23*).

Authors and editions

The basis for reconstruction of the most likely original Greek text does not need to be restricted to documentary witnesses alone, but may also include the results of modern scholarship. While the inclusion of every piece of textual commentary on the epistle to the Hebrews is well beyond the scope of this thesis, it is feasible to incorporate a sample, thereby allowing a comparison of theoretical reconstructions of the original text with documentary evidence.

Preferred readings have been noted from the editions of Merk (9th ed., 1964), Souter (2nd ed., 1947), Tasker (1964), Tischendorf (8th ed., 1872), the Oxford edition of *H KAINH DIAQHKH* (1873), which is the accepted standard used to represent the *Textus Receptus*, Westcott and Hort (1881a), Nestle and Aland (25th ed., 1963), and UBS4. As the editions of Bover (5th ed., 1968), Vogels (4th ed., 1955), and von Soden (1913) were not available for direct comparison, their preferences were reconstructed from the apparatus of *editionum differentiae* given in NA27 (1993, 766-7).

The preference at each variation unit has been taken to be that which is printed in the text, whether bracketed or not. Subsequent analysis techniques only allow one reading to be selected, so instances where editors give a marginal reading an equal claim to originality cannot be accommodated.

Although they never reached the stage of publication, G. D. Kilpatrick's handwritten amendments to his personal copy of *H KAINH DIAQHKH* (British and Foreign Bible Society, 2nd ed., 1958) were intended for a new edition. A photocopy of the pages covering the epistle to the Hebrews was kindly supplied by Dr. J. K. Elliott of Leeds University. Kilpatrick may not have altered this text in every place where he thought it necessary. Indeed, there is no handwritten amendment indicating his preference for the inclusion of *pistei mega" genomeno" Mwush"É* at Heb 11.23, which he had expressed elsewhere (Kilpatrick, 1980, 65). Nevertheless, it is probable that the amended text incorporates the bulk of his favoured readings.

Zuntz's *Text of the epistles* (1953), and the commentaries of Attridge (1989), Bruce (1990), Lane (1991a, 1991b), and Ellingworth (1993), complete the array of works from which modern scholarly positions have been gleaned. Along with Kilpatrick's text, they constitute what might be called 'quasi-editions' that specify preferred texts for substantial proportions of the sample variation units.

Criteria

At places of variation, certain critical principles may be used to discern which readings are most likely to be original. A set of criteria based on these principles has been compiled for the present study. The works of the previously mentioned editors and authors furnish instances of scholarly opinions that may be classified according to this set of criteria. Metzger's *Textual Commentary* (1994) and a number of journal articles have also been used as sources for the raw material of this categorisation procedure.

Summary

The object of this chapter is to identify the sources from which evidence concerning the ancient text of the epistle to the Hebrews is to be derived. A list of primary witnesses has been compiled. This is comprised of the accessible papyrus and uncial Greek New Testament manuscripts of Hebrews. Means of obtaining access to these manuscripts have been described as well. For completeness, it is important to consider

supplementary witnesses. These include the texts of minuscules, Church Fathers, versions, authors, and editors. The variation units of the UBS4 apparatus provide a convenient framework for incorporating samples of these important classes of evidence.

References

Aland, Barbara and Klaus Wachtel. 1995. 'The Greek minuscule manuscripts of the New Testament'. In *The text of the New Testament in contemporary research: essays on the status quaestionis*. Festschrift in honour of Bruce M. Metzger. Studies and documents, 46. Ed. Bart D. Ehrman and Michael W. Holmes. Grand Rapids: Eerdmans, 43-60.

Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *Novum Testamentum Graece*. Nestle-Aland, 27th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.

Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.

Aland, Kurt, Matthew Black, Carlo M. Martini, Bruce M. Metzger, and Allen Wikgren (eds.). 1983. *The Greek New Testament*. United Bible Societies, 3rd corr. ed. New York: United Bible Societies.

Aland, Kurt. 1994. *Kurzgefasste Liste der Griechischen Handschriften des Neuen Testaments*. 2nd ed. Berlin: Walter de Gruyter.

Aland, Kurt and Barbara. 1989. *The text of the New Testament: an introduction to the critical editions and to the theory and practice of modern textual criticism*. 2nd rev. and enlarged ed. Trans. Erroll F. Rhodes. Grand Rapids: Eerdmans.

Attridge, Harold, W. 1989. *The epistle to the Hebrews*. Hermeneia. Philadelphia: Fortress Press.

- Bearman, Gregory H. and Sheila I. Spiro. 1996. 'Archaeological applications of advanced imaging techniques'. *Biblical archaeologist* 59/1, 56-66.
- Brooks, James A. 1991. *The New Testament text of Gregory of Nyssa*. Society of Biblical Literature: the New Testament in the Greek Fathers, 2. Ed. Gordon D. Fee. Atlanta: Scholars Press.
- Bruce, F. F. 1992. 'Textual problems in the epistle to the Hebrews'. In *Scribes and scripture: New Testament essays in honor of J. Harold Greenlee*. Ed. David Alan Black. Winona Lake: Eisenbrauns, 27-39.
- Ehrman, Bart D. 1986. *Didymus the Blind and the text of the Gospels*. Society of Biblical Literature: the New Testament in the Greek Fathers, 1. Ed. Gordon D. Fee. Atlanta: Scholars Press.
- Ellingworth, Paul. 1993. *The epistle to the Hebrews: a commentary on the Greek text*. The new international Greek Testament commentary. Grand Rapids: Eerdmans.
- Elliott, J. Keith. 1989. *A bibliography of Greek New Testament manuscripts*. Society for New Testament Studies monograph series, 62. Cambridge: Cambridge University Press.
- H KAINH DIAQHKH*. 1873. Fascicle 7. Oxford: Oxford University Press. Repr. n.d. Chicago: University of Chicago Press.
- Kilpatrick, George D. n.d. 'Unpublished handwritten amendments to *H KAINH DIAQHKH* (British and Foreign Bible Society, 2nd ed., 1958)'. Courtesy of J. Keith Elliott, University of Leeds.
- Kilpatrick, George D. 1980. 'The text of the epistles: the contribution of Western witnesses'. In *Text & Wort & Glaube: Studien zur Überlieferung, Interpretation und Autorisierung biblischer Texte*. Festschrift in honour of Kurt Aland. Ed. Martin Brecht. Arbeiten zur Kirchengeschichte, 50. Berlin: Walter de Gruyter, 47-68.

- Lane, William L. 1991a. *Hebrews 1-8*. Word biblical commentary, 47A. Dallas: Word Books.
- Lane, William L. 1991b. *Hebrews 9-13*. Word biblical commentary, 47B. Dallas: Word Books.
- Lundberg, Marilyn J. 1992. *A descriptive list of holdings*. 2nd ed. Claremont: Ancient Biblical Manuscript Center.
- Merk, Augustine (ed.). 1964. *Novum Testamentum Graece et Latine*. 9th ed. Rome: Pontifical Biblical Institute.
- Metzger, Bruce M. 1994. *A textual commentary on the Greek New Testament*. 2nd ed. Stuttgart: Deutsche Bibelgesellschaft.
- Mullen, Roderic L. 1997. *The New Testament text of Cyril of Jerusalem*. Society of Biblical Literature: the New Testament in the Greek Fathers, 7. Ed. Bart D. Ehrman. Atlanta: Scholars Press.
- Nestle, Eberhard and Kurt Aland (eds.). 1963. *Novum Testamentum Graece*. Nestle-Aland, 25th ed. Stuttgart: Wŷrttembergische Bibelanstalt.
- Osburn, Carroll D. 1995. 'The Greek lectionaries of the New Testament'. In *The text of the New Testament in contemporary research: essays on the status quaestionis*. Festschrift in honour of Bruce M. Metzger. Studies and documents, 46. Ed. Bart D. Ehrman and Michael W. Holmes. Grand Rapids: Eerdmans, 61-74.
- Souter, Alexander (ed.). 1947. *Novvm Testamentvm Graece*. 2nd ed. Oxford: Clarendon Press.
- Tasker, R. V. G. (ed.). 1964. *The Greek New Testament: being the text translated in The New English Bible 1961*. Oxford: Oxford University Press.
- Tischendorf, Konstantin von (ed.). 1872. *Novum Testamentum Graece*. Vol. 2. 8th major critical ed. Leipzig: Giesecke and Devrient. Repr.

1965. Graz: Akademischen Druck.

Wachtel, Klaus and Klaus Witte. 1994. *Das Neue Testament auf Papyrus*. Vol. 2. *Die Paulinischen Briefe*. Part 2. *Gal, Eph, Phil, Kol, 1 u. 2 Thess, 1 u. 2 Tim, Tit, Phlm, Hebr*. Arbeiten zur neutestamentlichen Textforschung, 22. Berlin: Walter de Gruyter.

Westcott, Brooke Foss and Fenton John Anthony Hort (eds.). 1881a. *The New Testament in the original Greek*. Vol. 1. *Text*. Cambridge: Macmillan. Repr. 1974. Graz: Akademische Druck.

Westcott, Brooke Foss and Fenton John Anthony Hort. 1881b. *The New Testament in the original Greek*. Vol. 2. *Introduction [and] Appendix*. Cambridge: Macmillan. Repr. 1974. Graz: Akademische Druck.

World of learning. 1995. 46th ed. London: Europa Publications.

Zuntz, GŸnther. 1953. *The text of the epistles: a disquisition upon the corpus Paulinum*. Schweich Lectures of 1946. London: British Academy.

TRANSCRIPTION

Synopsis

A major part of this thesis is concerned with the development of the text of the epistle to the Hebrews as recorded in papyrus and uncial Greek manuscripts. A transcription system is employed to record the witness of these manuscripts, including corrections. The different editorial stages of each manuscript can then be separated and compared with those of the other manuscripts.

The ultimate transcription system would allow ready storage and extraction of perfect manuscript descriptions. In reality, the information capture process is beset by limitations, so practical transcriptions only give approximate representations of manuscript contents.

Separation into components assists comprehension of the whole. A transcription may be thought of as a series of information layers which correspond with the developmental stages in a manuscript. These proceed from preparation of the writing materials and instruments, through laying down the biblical text and various paraphernalia, to completion and subsequent changes. The corresponding information layers provide more or less complete documentations of these stages, and may be visualised as a set of transparencies laid over an image of the basic writing medium. The first transparency would be the text of the original scribe. The next few transparencies might show the amendments of correctors, with one transparency allotted to each corrector. Commentaries, titles, and tables that embellish the base text could be added as well.

Computer-oriented transcription

A transcription is a translation which requires interpretation of written symbols and is not a mere mechanical reproduction (Robinson, 1994a, 6). Given this, a good transcription system might be expected to be like a good translation: contemporary yet future-proof; succinct yet unambiguous; accurate, beautiful, dignified, and clear; conveying the meaning of the original to the recipients in an unmolested and

understandable form. It would reveal that which had formerly been hidden.

Reveals the hidden

The preface to the first American edition of the Contemporary English Version of the Bible (CEV, 1995, 1628-30) makes reference to translation principles underlying some influential editions of the Bible. It includes quotes from the Authorised Version translators and from Martin Luther. I will use a number of these quotes to introduce discussion on certain aspects of transcription. (The CEV has modernised the Authorised Version translators' English.)

Translation it is that opens the window, to let in the light; that breaks the shell, that we may eat the kernel; that puts aside the curtain, that we may look into the most holy place; that removes the cover of the well, that we may come to the water (CEV, 1995, 1628).

In many respects the Greek New Testament manuscripts are locked away from view. Although magnificent efforts have been made to bring them to light in the past, experience shows that there is a real danger of their once again becoming lost to all but a few. Tischendorf spent his life documenting the witnesses to the Greek New Testament, but over a century later many of his works have become so rare that they are exceedingly difficult to obtain. Critical editions are not enough for those who require complete evidence – that is, evidence which has not been orthographically levelled. Translation into computer-readable textual and graphical forms promises to make the manuscripts accessible once and for all.

Conveys the meaning

Greek New Testament manuscripts contain a text which has numerous levels of literary and linguistic meaning. Different recipients, whether human or machine, have different requirements. Scholars may be interested in syntax, morphology or orthography, whereas computers need structured input in order to produce structured output. The aspects that pertain to human readers should be understandable in their context and those which pertain to computers should be error free. The reverse is also true: computers require a transcription that they can process, and

humans desire an accurate representation of the evidence.

A good transcription is capable of conveying the meaning of the text to the recipients in an unmolested and understandable form. It is appropriate for the task at hand and encodes essential and interesting features efficiently without resorting to procrustean measures. Luther wrote that naturalness helps to make translations understandable:

We do not have to enquire of the literal Latin, how we are to speak German. Rather we must enquire about this of the mother in the home, the children in the street, the common man in the marketplace. We must be guided by their language, the way they speak, and do our translation accordingly (CEV, 1995, 1628).

Inclusion of relevant data alone in a manner which allows the extraction of a clear representation assists human comprehension. Use of standard encoding methods gives transcriptions greater utility in the computer realm.

Accurate, beautiful, dignified, and clear

Accuracy is ensured by adequate quality control. Ideally, the frequency of transcription errors would be zero. In reality, checking strategies can significantly reduce, but never eradicate, the possibility of mistakes. The best that can be achieved is reduction below an acceptable limit.

Beauty and dignity are not qualities normally associated with computers. Computer-oriented transcriptions look ugly and common when compared with the manuscripts from which they are derived. Yet, with subsequent processing they can be displayed in elegant fashion.

Clarity is a necessary result of a well founded system and recurs at various levels. If the specification for a transcription system is properly thought out, resultant transcriptions will be processed to higher levels with ease. Once processed, the multiple texts of the manuscripts can be clearly presented as a complete collation for comparison of individual variations. Computer representations of texts are not subject to the same order of spatial limitation as the printed form. Instead of a reader being compelled to decipher a critical apparatus, manuscript evidence can be

presented clearly in parallel line fashion so that relative variation can be appreciated at a glance. Multivariate analysis of the same collation can provide graphical displays which have the potential to provide new insights into the relationships between the various witnesses.

Succinct yet unambiguous

Some aspects of translation require a compromise. Conversion from one semantic system to another is frustrated when their elements do not exactly correspond. Luther said that a translator should grasp the meaning of the original then forget its idiom and reproduce its meaning according to the rules of the destination language:

Whoever would speak German must not use Hebrew style. Rather he must see to it Ñ once he understands the Hebrew author Ñ that he concentrates on the sense of the text, asking himself, ÒPray tell, what do the Germans say in such [a] situation?Ó Once he has the German words to serve his purpose, let him drop the Hebrew words and express the meaning freely in the best German he knows (CEV, 1995, 1629).

Sometimes a translator is obliged to use many words to reproduce the original meaning. An analogous approach makes computer transcriptions verbose, adding to the tedium of transcription. The opposite strategy supplies less information in the understanding that the reader can make sense of resultant ambiguities, but is not appropriate in the present context because computers do not have the ability to think.

In view of this, a computer-oriented translation should use one-to-one correspondence between source and destination texts where that is sufficient, and create new vocabulary where it is not. For example, what is clearly an *alpha* can be transliterated as such, but a new element can be created to represent a letter which is probably, but not certainly, an *alpha*. A tagging system is ideal for this purpose.

The transcription process is facilitated by confining its scope to the area of interest. An almost infinite amount of information could be encoded, but it is better to concentrate on essentials, especially in view of practical limitations. These are primarily the patience and determination of the transcriber Ñ resources which are too quickly depleted.

Contemporary yet future-proof

To return to the analogy of translations, some translators attempt to be contemporary by incorporating slang terms and local idioms. These are prone to obsolescence and only appeal to a narrow audience. On the other hand, the Authorised Version proved to be remarkably future-proof. Even today, an English speaker will understand its phrases though they are in a form which has not been spoken for centuries. One reason for its longevity is that contemporary English is not too distant from that of King James. Had it been written in Middle English, few would try to read it now.

Standard Generalised Markup Language (SGML) is a text description language, unique in having been accepted as an international standard. It describes text and textual structure rather than specifying how to process text (Robinson, 1994a, 29-30). One of its progeny is the hypertext markup language (HTML) which is the basis of World-Wide Web communication. Another descendant which is more relevant to this discussion is the Text Encoding Initiative (TEI), 'an international project to develop guidelines for the preparation and interchange of electronic texts for scholarly research' (Plotkin and Sperberg-McQueen, 1996, 1). This is the standard among humanities-based computers and texts projects, although there are other systems which may be better for the present task, such as the Multi-element Code System (MECS) being employed to transcribe the Wittgenstein archives at the University of Bergen. Whichever of these particular systems prevails in the future, the acceptance of SGML as an international standard means that any transcriptions made with a compatible system will be contemporary yet future-proof.

Tolerates uncertainty

As the Authorised Version translators observed, sacred texts are not immune from uncertainty:

É it has pleased God in His divine providence here and there to scatter those words and sentences of that difficulty and doubtfulness, not in doctrinal points that concern salvation (for in such it has been vouched that the Scriptures are plain), but in matters of less moment, that fearfulness

would better beseem us than confidence. For as it is a fault of incredulity, to doubt those things that are evident; so to determine of such things that the Spirit of God has left (even in the mind of the judicious) questionable, can be no less than presumption (CEV, 1995, 1630).

Uncertainties can be due to imperfect knowledge of the manuscripts or imperfections in them. The former class may be caused by inexperience on the transcriber's part, but is commonly the result of poor resources. Good quality reproductions of manuscripts are often difficult, if not impossible, to obtain. A transcription mechanism that tolerates various kinds and degrees of uncertainty is therefore necessary. The tagging of uncertain items enables the computer to handle what is better described as a mixture of a set of alternatives rather than one or another of that set.

Open-ended

To a certain extent, translations reflect the idiosyncrasies of the translator and may even contain errors. The translators of the Authorised Version recognised this when they wrote the following:

Variety of translations is profitable for the finding out of the sense of the Scriptures. We affirm and avow that the very meanest translation of the Bible in English contains the Word of God, nay is the Word of God. [There is no reason] why the Word translated should be denied to be the Word, or forbidden to be current, notwithstanding that some imperfections and blemishes may be noted in the setting forth of it (CEV, 1995, 1630).

In the same manner, new perspectives on the contents of a manuscript can enhance existing transcriptions. Improvements might consist of a supplementary grammatical analysis of formerly transcribed words, or a list of errors discovered through revision. One must decide whether to amalgamate the new perspective into the existing work or to keep it as an associated but separate entity. It is important not to discard former versions, even if they contain imperfections. They are useful for archival purposes, and may even contain insights which later versions miss.

Amalgamating new perspectives is advantageous in certain situations, as with the assignment of scribal alterations. Errors are less likely if the sequence of changes is put down in one place instead of in a set of

corresponding transcriptions because the transcriber does not have to switch back and forth between the parallel versions as the sequence is unravelled. Another advantage of this approach is compactness, because redundant information is not repeated.

Whereas amalgamated transcriptions must be processed to extract distinct views, keeping new perspectives separate allows immediate access to each one. Greater storage space is required for multiple perspectives. Even so, this cost has the associated benefit of avoiding the difficulties of squeezing a number of perspectives into a single description.

Individual implementations of SGML such as the TEI are better suited to the amalgamation approach because they assume that everything about a text can be incorporated into a single, sequential description. As a result, they have trouble coping with textual features such as overlapping structural divisions which are difficult, if not impossible, to transform from a parallel to a sequential representation. Significant as they are, these difficulties do not prevent sequential transcription methods from being sufficient for most purposes, especially the primary task of transcribing the texts of a manuscript's scribe and correctors.

It is difficult to foresee from the beginning exactly which features of a manuscript deserve to be included, so it is important to be able to incorporate new information as required. In general, it is easier to add details within an existing structure than to redesign the structure itself. If alterations are necessary, a list of changes or entire copies of former versions may be stored for archival purposes.

Documented and convenient

The translators of the Authorised Version gave an account of their methods to their readers:

Neither did we think much to consult the translators or commentatorsÉ but neither did we disdain to revise that which we had done, and to bring to the anvil that which we had hammered; but having and using as great helps as were needful, and fearing no reproach for slowness, nor coveting praise for expedition, we have at length, through the good hand of the

Lord upon us, brought forth the work to that pass that you see (CEV, 1995, 1630).

A transcription system should also be specified by: documenting the system itself; declaring general editorial principles; indicating sources, including authority and other bibliographical details; and keeping a log of revisions. Procedures should be in place to deal with normally encountered phenomena and to note important features. However, if they are too laborious, what is already a tedious task will require a superhuman effort. In other words, it will never be accomplished.

As well as being appropriate for the transcriber, the system should accommodate the computer's needs by being translatable to SGML. An inherently descriptive approach, as opposed to a prescriptive approach, will assist this process. The scribe's intention is the primary consideration, not his or her method. It is therefore better to write 'this word is deleted with strokes' rather than 'place a stroke through each letter'. As Robinson (1994a, 30) writes, 'the encoding does not tell us what to do with the text. Rather, it tells us what the text *is*.'

Transcription should make use of available helps. Optical character recognition (OCR) is often suggested as an aid to large transcription projects, but proves to be a false hope. Present systems are hard pressed to recognise a clearly typed page, let alone handwriting. Some more sophisticated and expensive systems are trainable, so can be applied to handwritten texts. No doubt, this technology will improve until it is able to scan manuscripts. Once machines become capable of recognising handwriting with a high level of accuracy, basic transliteration will become automatic but the task of descriptive annotation which produces useful transcriptions will still be an exclusively human domain.

Other helps that are now making their first appearance include text editors that facilitate tagging and production of SGML output. These are most welcome, but it would be a great advantage to have transcription tools that facilitated the encoding of parallel representations of a manuscript. Such an aid would be very useful if it could take account of the hierarchy of layers in a particular transcription project. As an example of what would then be possible, text in a layer corresponding to

the first hand of a manuscript could automatically become the base text of the layer corresponding to the second hand.

In some circumstances, it would be useful to describe uncertain features by means of probabilities. For example, where a letter appeared most likely to be an *alpha*, but was, perhaps, a *lambda* or even a *delta*, the relative probabilities could be described as $P(A) = 0.6$, $P(L) = 0.3$, $P(D) = 0.1$. This kind of description will be derivable from OCR systems, once they attain the necessary level of competence. Without automation, the transcriber would be required to estimate a probability for each uncertain element. Such estimates are subjective and exceedingly dreary to enter. By contrast, a scheme of three levels labelled 'certain', 'uncertain', and 'speculative' has been found to be quite workable for manual entry, and less prone to subjectivity. In this context, 'certain' means beyond reasonable doubt, 'uncertain' implies that there are a few alternative possibilities, while 'speculative' indicates many alternatives. In the example just given, the *alpha* would simply be labelled 'uncertain'.

Another potential help to transcribing New Testament manuscripts is the World-Wide Web. Given a standard transcription system and electronic images, many could contribute towards finishing this colossal task. There are over 5000 Greek manuscripts alone. Eventually, one would hope that the most important manuscripts could be translated to machine-readable texts, thereby constituting an easily accessible treasury for scholars and anyone else who might be interested.

Transcription system specification

This discussion has identified desirable characteristics of a practical computer-oriented transcription system. Such a system should be:

Accessible, making manuscript texts available once and for all;

Accurate, reducing error rates through quality assurance strategies;

Convenient, being suited to manuscript transcription, confined to the area of interest, sufficient for the task but not too laborious, and making use of available helps;

Standardised, employing a standard encoding system;

Structured, allowing subsequent processing and extraction of multiple, perspective-dependent views;

Probabilistic, tolerating degrees of certainty in data;

Expandable, providing for the incorporation of new perspectives;

Revisable, being open to revision and error correction;

Documented, specifying the transcription system itself, declaring general editorial principles, allowing annotation of transcriptions, indicating sources, and identifying transcribers; and

Archival, keeping a record of revisions and former versions.

These requirements are largely fulfilled by an SGML compatible system which is tailored to cope with relevant characteristics of the manuscripts to be transcribed, provided that procedures to ensure maintenance of quality control and archival records are included. The *Collate* transcription system, as specified in the manual accompanying the program *Collate 2* (Robinson 1994b), is suitable for the purpose and has been adopted for the transcriptions in this thesis. It is compatible with the recommendations of the Text Encoding Initiative (Robinson 1994c, 45) and, therefore, with SGML. It was readily customised to encode the desired features of the manuscripts under study. With the addition of various error-checking procedures and archival descriptions, it satisfies the specifications given earlier.

Using the *Collate* transcription system

What follows is an illustration of the *Collate* transcription system as applied to folio 28 verso of P46 (Heb 7.20-28). If F. G. Kenyon's edition of *The Chester Beatty biblical papyri* is available, the plates (1937) and his transcription (1936) can be consulted to clarify the process.

Complete transcription

The manuscripts are transcribed exactly as found. Spelling and punctuation are included because these particulars contain information which may be pertinent to the history of the text. Use of a font which closely approximates the appearance of uncial script reduces the incidence of transcriptional errors such as typing 'P' in place of *rho* or 'C' in place of *sigma*. The Greek font used in this section was especially created to fulfil this condition.

Basic text

Rather than typing in the entire text of the manuscripts, the text of UBS3 (1983) was used as a basis for transcription. After it had been obtained in electronic form, accents and punctuation were removed, final *sigmas* were converted to normal *sigmas*, and the entire text was capitalised. Fig. 1 gives the correspondence between Greek and Roman letters employed, as well as numerical equivalents.

Location markers

The page under scrutiny is folio 28 verso according to the modern editors, or *nu delta* (i.e., 54) according to one of the manuscript's correctors. The folio numbering is transcribed as:

[f 28v][p [c4]ND[/c4]]

Whereas the transcriber is free to use whichever set of location symbols is desired, those used here are based on *Collate* defaults. Lower case characters within location markers ([É]) specify folio, page, section, column, and line number. The assignment of the number *nu delta* to the fourth corrector is indicated by enclosure in the matched opening and closing tags [c4] and [/c4]. (Corrector assignments will be discussed subsequently.)

The specialised font mentioned earlier prints Greek uncials for upper case and Roman letters for lower case. Transcription files which use this font are easier to read. In conjunction with lower case manuscript labels, it enables a collation program to produce printer-ready output using a single font.

Diacritics

The first line of the folio is transcribed as:

MOSIAS EISIN [di]I[/di]EREIS[c3]'[/c3] OI MEN GAR CWRIS OR=

[di]I[/di] indicates diaeresis above the *iota*, while [c3]'[/c3] transcribes a reading mark inserted by the third corrector.

Word and line division

Words are separated according to the divisions of the standard text unless the positions of features such as diacritics and punctuation suggest that a manuscript divides them differently. Line divisions in the manuscript are marked with a carriage return. (In the examples given below, line-divisions sometimes occur because of the word-processor's word-wrap facility and do not correspond to line-divisions in the manuscript. The actual carriage returns can only be seen in a processor capable of displaying them.) A concatenation marker (=) precedes the carriage return when a line-division does not coincide with a division between words. This enables the collation program to reconstitute words divided across lines before collation.

Block markers

The next line introduces a block marker <ch 7><v 21> identifying the chapter and verse:

KWMOSIAS GEGONOTES[c3]'[/c3] <ch 7><v 21> O MET ORKWMOSIAS

The inclusion of block markers is important because collation programs use them for navigation. All tags must have matching opening and closing sequences within a block, otherwise collation errors may occur. Where tagged text spans a block marker, a closing sequence must be inserted immediately before the block marker and an opening sequence inserted immediately after. (An example of this is given below in the discussion of reconstructed text.)

Scribal contractions

The following line introduces a *nomen sacrum*, [ns]KS[/ns]:

DIA TOU LEGONTOS PROS AUTON WMOSEN [ns]KS[/ns]

The last two letters of the eighth line have a line drawn above them which is scribal shorthand for a final *nu*:

DIA TO QANATW KWLUESQAI PARAMEN[fn]EI[/fn][c3]'[/c3]

At the eleventh line a KAI compendium has been inserted above the line by the first corrector:

<ch 7><v 25> OQEN [c1][st][kc]K[/kc]/[st]/[c1] SWZEI EIS TO PANTELES
[c3]'[/c3] DUNATAI

Working from the inner-most tags outwards, [kc]K[/kc] represents a tailed *kappa* which is a KAI compendium. The tags [st]É[/st] indicate superscript text, while the [c1]É[/c1] tags show that this is an alteration by the first corrector. As the tags are nested, the question of an order of precedence arises. The rule followed here is that tags which are to be 'regularised' first should bind the most tightly to the text being tagged. (Regularisation refers to the replacement of one item with another before collation. In this case, [kc]K[/kc] might be replaced by KAI.) A corollary to this rule is that tags which need to be retained for later stages of processing, including those relating to correctors and text certainty, should be placed outermost. Corrector tags have a higher precedence than uncertain or reconstructed text tags to enable separation of correctional stages without loss of information.

Scribal contractions are widespread, especially in the later manuscripts. Many of the corresponding shorthand symbols are listed in Gardthausen's *Griechische Palaeographie* (1913). Contractions besides those already mentioned are transcribed by enclosing the symbolised letters in [sc]É[/sc] tags. If a symbol is written above the rest of the text it is also enclosed in superscript tags. This allows it to be ignored if an automated count of line lengths is to be performed.

It would be more consistent to treat KAI compendia, *nomina sacra* and final *nu* superscript lines as particular instances of scribal contraction. This could be achieved by using nested tags in the *Collate* system (or

tags with attributes in SGML). A KAI compendium would then be represented by [sc][kc]K[/kc]/[sc]. The present transcriptions do not use this double tagging method, but they could easily be converted if a more general analysis of scribal contraction was desired.

Doubtful and obliterated text

The next line introduces the uncertain text tags [ut]É[/ut]:

TOUS PROSERCOMENOUS DI AUTOU TW [ns][ut]Q[/ut]W[/ns]

These enclose any letters which, upon examination, could possibly be one of a number of letters, say two to five. This category is roughly equivalent to letters with sublinear dots in conventional editions. Practically the whole uncial alphabet is prone to confusion once the writing has deteriorated:

A L D S E O Q G H P T F I R U Y K C M N Z X

The remnant of the uncertain letter in the example is consistent with only a handful of letters. Even though one would expect to find a *theta* before an *omega* with a *nomen sacrum* superscript line at this place, the fact remains that the information content of the letter itself has decreased to the level of ambiguity. If the transcriber resists the temptation to let context influence decisions concerning certainty, it is reasonable to expect that these transcriptions will be similar to those generated by optical character recognition (OCR) scanners, once they are successfully applied to the task.

Two lines further down, the tags [rt]É[/rt] appear:

KAI EPREPEN ARCIEREUS OSIOS AKAK[ut]O[/ut][rt]S[/rt]

These identify reconstructed text, which consists of letters which are either entirely missing or which are so ambiguous that they could be any letters. This class includes text which conventional manuscript editions enclose in square brackets, thus indicating a lacuna. It also includes letters which are very indistinct, but which may still be marked by sublinear dots in printed editions.

This scheme has served the purpose of assigning levels of certainty well. However, it has a deficiency. The problem relates to there being no distinction between obliterated letters for which the base is intact, and letters absent because of lacunae. As a result, the transcriptions do not make clear the exact boundaries of the extant writing material. For this reason, future transcription systems should include yet another category for lacunae. The 'reconstructed text' category should be renamed 'speculative text', and be used only for obliterated letters where the base remains. In my opinion, it is important to retain a separate category for such text. To remove it results in the loss of distinction between letters of which a transcriber is reasonably confident, and those where almost complete uncertainty prevails.

Returning to the example, if reconstructed text is ignored, it implies that the word here is AKAKO rather than the word AKAKOS with an indefinite final letter. This could be transcribed as AKAKO_, where the underscore represents obliterated text. A problem with using a single character such as an underscore to represent all reconstructed text is that collation programs can become confused where large portions of a reconstructed block are represented in this way. One possible solution would be to construct a character set which gives corresponding certain, uncertain and reconstructed letters different appearances. The collation program would then be instructed to treat the corresponding letters as equivalent for the purpose of collation, while the program's output would give a visual indication of the text's certainty.

A warning is necessary with respect to reconstructed text. Tags required for later stages of processing (such as corrector tags) should not be placed within text that is tagged as reconstructed. This is because a preprocessing step, such as replacing everything within reconstructed text tags by an underscore (_), can eliminate the required tags unintentionally. Experience has shown that it is always possible to rearrange the tagging so that this does not happen.

Where tagged text encompasses a block marker, a closing tag should be put at the end of one block and an opening tag placed at the beginning of the next block. To illustrate, the block marker <ch 7><v 20> is preceded

by a closing tag [/rt] and followed by an opening tag [rt] in the transcription of the last line of folio 27 recto:

```
[rt]TW [ns]QW[/ns][rt] <ch 7><v 20> [rt]KAI KAQ OSON OU CWR[/rt][ut]IS  
OR[/ut][rt]KW[/rt]=
```

Where only part of a block's text is preserved, the rest should be supplied as reconstructed text to help collation programs stay on track. This requirement may change as collation routines become more sophisticated.

Fragmentary manuscripts sometimes contain enough information to narrow the range of possibilities for reconstructed text. The surviving fragments may indicate that a lacuna is more likely to hold one reconstruction than another. For large lacunae, where educated guesses about the most likely text are precluded, a single standard text should always be used to supply the missing text. In this way, variants within reconstructed text will always be due to a conscious choice that one possible reading is more likely than another.

It is tempting to use more than one standard text in certain situations. For example, it may be known that a particular manuscript conforms to one standard rather than another, as in the case of manuscripts with a substantially Byzantine text conforming to the *Textus Receptus*. However, to use both the UBS text and the *Textus Receptus* results in at least two undesirable outcomes.

The first is the result of differing verse division positions which sometimes occur. A collation program which uses verse divisions to mark collation block divisions will interpret two texts with different division positions as being variant even though no variation exists in the texts themselves.

The second occurs where different standards are used for reconstructed text regardless of what is likely to fit the gaps. Given two manuscripts with lacunae covering the same extensive section of text, apparent variations will be found where the standard texts happen to differ, but where the actual manuscript texts are completely unknown.

Spaces, punctuation, breathings, and accents

Among the early papyri, there are sometimes spaces between words which coincide with pauses in sense. An example of the inclusion of an ellipsis (Ê) to indicate such a space occurs in the seventeenth line.

AMARTWLWNÉ K[ut]A[/ut]I [ut]U[/ut]YHLOTEROS TWN

It is difficult to find a satisfying way to define these spaces. For convenience and consistency, the simple criterion that they must exceed a certain dimension may be used, although this can result in authentic spaces being omitted.

These transcriptions include three classes of punctuation: upper, medial, and lower. Colons and apostrophes are transcribed as such, while paragraph divisions are marked with a paragraph symbol (§).

Breathing and accent marks are not usually transcribed as they are not within the scope of this study. Their inclusion would entail a great deal of extra work for little return with respect to discovering the early history of the text. Therefore, they are only transcribed if they were written by the earlier scribes or correctors.

Where they are transcribed, the present system labels these marks with tags such as [rb]O[/rb] for a rough breathing. As an alternative, it would probably be better to use SGML-type entity references for highly accented texts. They consist of a standard abbreviation for the combination of letter and diacritic inserted between an ampersand and semi-colon. Accordingly, an omicron with a rough breathing would be transcribed as &Orougr; (TEI classical Greek supplemental, 1992). Other combinations and ligatures could also be transcribed by this method.

Implied original disposition

The last few lines of the folio are transcribed as:

EAUTON ANENEGK[ut]A[/ut]S[c3]'[/c3] <ch 7><v 28> O NOMO[rt]S GAR
KA[/rt]=
[rt]QISTHSIN ANQRW[/rt][ut]P[/ut]OUS [di]I[/di][rt]EREIS ECONTAS[/rt]

[rt]ASQENEIAN O LOGOS DE THS ORKWMOSIAS[/rt]

This varies from Kenyon's transcription (1936, 33):

eauton anenegkas³/₄ o nomo»s gar kaqi
sthsin arciereis anqrw¹/₄pous »econtas
»asqeneian o logos de ths orkwmosias¹/₄

The difference lies mostly in the word order of the reconstructed text. Given that not too large a reconstruction is attempted, a particular original disposition is often implied. After removing characters such as punctuation and spaces, the range of possible reconstructions that are compatible with the manuscript evidence can be narrowed by considering line-lengths, likely locations of line-divisions, and possible textual variations.

To demonstrate that this is so, the relevant parts of my reconstruction can be compared with Kenyon's reconstruction:

EAUTONANENEGK ASONOMOSGARKA
QISTHSINANQRW POUSIEREISECONTAS

EAUTONANENEGK ASONOMOSGARKAQI
STHSINARCIEREISANQRW POUSECONTAS

The spaces correspond to a vertical split in the papyrus. As may be seen, the first reconstruction conforms better to the disposition of the writing on the papyrus. This procedure of rearranging the text with the assistance of a word processor using a font that is similar to the manuscript's writing, contributed to the discovery of a previously unpublished variant in P46 at this location (Finney, 1994).

Scribal alteration

Through transcribing a number of manuscripts of Hebrews, a system for assigning and tagging scribal corrections has been developed. The heart of the system is a decision table which lists criteria used to discriminate

between correctors:

Corrector	0	1	2	3	4	5	Ambiguous
Style		x					
Size							x
Pen-width		x					
Shade							x
Kenyon		x					

Corrector '0' is the original scribe correcting his own work, corrector '1' is the first corrector, and so on up to corrector 'x'. The last classification is for all corrections which cannot be assigned to a specific corrector with confidence. *Style* relates to the handwriting, *size* to the dimensions of the letters, *pen-width* to the width of the stylus, and *shade* or *colour*, as the case may be, to ink characteristics.

None of these characteristics is an infallible guide to identity. However, when taken together they do give a basis for consistent assignments. The opinions of various editors and commentators can be included, and each criterion may be weighted to reflect its importance or reliability. Where the decision table gives an evenly divided or indeterminate result, the correction can be assigned to the unidentified corrector 'x'. In this hypothetical example, the assignment falls quite strongly to the first corrector.

Corrections which involve changes to existing words are transcribed as deletion of the original and replacement with the corrected word, even if only part of the word is affected. The eighth line of folio 28 recto provides an example of this procedure. The first corrector has crossed out the *iota* in ANQRWPOIS:

[d1]ANQRWPOIS[/d1] [c1]ANQRWPOS[/c1]

Nested deletion and correction tags are used where more than one corrector has been at work on the same words. Whereas individual letters can be marked as added or deleted, such an approach makes it more difficult for a reader to comprehend the stages of correction.

It is necessary to know the number of scribes and correctors of a manuscript and their distinguishing features before a decision table can be constructed. The requisite knowledge is gained by examining numerous alterations. The notes of others who have edited the manuscript can also contribute valuable instruction. Even so, subtle differences between correctors sometimes go unnoticed until a transcription is well advanced, and might call for a complete revision of former assignments.

As the text is subject to uncertainty, so there can be degrees of doubt in the assignment of alterations. The present system includes the unidentified corrector category to handle this, but a better system would allow graduated assignment to a number of possible correctors if the evidence was ambiguous. Given the example of an alteration which the transcriber regards as probably by the second corrector, but possibly by the original scribe or first corrector, the assignment could be given as a probability: $P(0) = 0.3$, $P(1) = 0.1$, $P(2) = 0.6$.

Unfortunately, such a system would become complicated if a number of related alterations had been made because the relevant probabilities would be interdependent. Changing the probabilistic description of one correction would require logical rearrangement of each related correction. This volatile tendency would be made less troublesome by the construction of a transcription aid which dealt with these problems in a manner similar to the way in which a spreadsheet processes related quantities. As additional information was included, linked assignments could be altered automatically.

Summary of specialised tags

The specialised tags which have been developed to adapt the *Collate* transcription system to the manuscripts under study are collected together in fig. 2.

Referenced notes

An essential transcription requirement is the ability to make referenced notes to important features. In the *Collate* system, notes can be placed

within the transcription, enclosed by suitable characters which are normally curly brackets {}. The present study has separated transcription notes from the transcriptions themselves as this is more suitable to the printed medium. Each note is referenced to a verse and word or line within the transcription.

A hypertext approach would be ideal for transcription annotation. Each word or passage for which a note exists could be provided with a hypertext link to the note's location. This would allow the reader to switch between the transcription and the associated notes with ease.

Error reduction

Transcriptional errors are very likely to occur in the absence of quality control strategies. Even with error reduction procedures in place, the possibility of mistakes is never completely removed. The best that can be achieved is to reduce error rates to an acceptable level.

Ideally, transcriptions are made by two people who do not discuss their common task. The results are then collated by a third person who can make decisions on points of disagreement. This method is not practicable when only one person is available to transcribe a particular manuscript, in which case self-checks are necessary.

Two major methods have been employed to improve the integrity of the transcriptions made for this study. The primary one consists of going through the transcription process twice for each manuscript. Reading the transcription aloud as it is checked against the original makes error detection more effective. Text to speech conversion is now possible with personal computers, and could be put to good use in this context.

The next tactic employs computer processing to check for tag errors in transcriptions. These are difficult to detect visually, but are easily found by a program which searches for unmatched pairs of tags and tag enclosure characters. Transcription mistakes may also be found at the collation stage, because words that differ from their analogues in other manuscripts tend to be highlighted.

There is a class of error which is particularly difficult to locate. As mentioned before, each transcription is made from a single standard text. The lapse occurs when a manuscript word differs from the corresponding standard word, but the transcriber does not record the variation. Only the primary kind of check will reveal such an error; it cannot be found through collation or tag checks.

I have not attempted to estimate the error rate of my unchecked transcriptions, although it would be an interesting exercise to do so. I would hazard a guess that it is of the order of one per hundred words. The rate for checked transcriptions is significantly lower – perhaps one error per five thousand words.

Documentation

The task of transcription is not restricted to recording the text of manuscripts alone, but should be supplemented with information on the transcription process as well. If a transcription is properly documented, others should be able to understand precisely how the transcriber arrived at the end result.

One component of this documentation is a specification of the transcription system itself. In the present case, this has already been addressed in the preceding discussion.

The editorial principles underlying a transcription comprise another essential aspect of the description. The means of dealing with commonly encountered manuscript phenomena should be clearly set out. Issues peculiar to a particular manuscript can also be explored. Annotations are needed to register decisions made in relation to passages which have challenged the transcriber in one manner or another, as previously discussed under the heading of referenced notes.

To complete the record, the reader should be informed of: the authority upon which a transcription is based, whether the manuscript itself, a facsimile, or an edition; the identity of the transcriber; and the title of the transcribed text. It is also advisable to include commencement and completion dates for archival purposes.

An appendix to the transcription forms a suitable repository for documentation which is specific to the source manuscript. Another possibility is to record specific information in a standard template or 'header' placed at the beginning of the transcription.

Archives

An archive is desirable not only as a repository of completed transcriptions, but also as a register of the revision history of each transcription. Valuable facts may be gleaned from an archive which is set up in this way – a transcriber's error rate could be calculated by comparing initial and revised versions of the same transcription. Good archival practice also reduces the risk of catastrophically losing the fruits of so much long, hard, lonely labour. The transcriptions undertaken for this thesis represent two years of full-time work.

Summary

This chapter sets out the desirable characteristics of a good transcription system. The *Collate* system has nearly all of these characteristics. It is readily adapted to the present purposes by using a customised tagging system, along with error reduction, documentation, and archiving strategies. The resultant system has proven capable of producing adequate transcriptions of the pertinent Greek New Testament manuscripts which should continue to be useful in the future.

Fig. 1: Transliteration scheme

<i>Letter</i>	<i>Uncial</i>	<i>Minuscule</i>	<i>Number</i>
<i>alpha</i>	A	a	1
<i>beta</i>	B	b	2
<i>gamma</i>	G	g	3
<i>delta</i>	D	d	4
<i>epsilon</i>	E	e	5
<i>waw (digamma)</i>	-	-	6
<i>zeta</i>	Z	z	7
<i>eta</i>	H	h	8
<i>theta</i>	Q	q	9
<i>iota</i>	I	i	10
<i>kappa</i>	K	k	20
<i>lambda</i>	L	l	30
<i>mu</i>	M	m	40
<i>nu</i>	N	n	50
<i>xi</i>	X	x	60
<i>omicron</i>	O	o	70
<i>pi</i>	P	p	80
<i>koppa</i>	-	-	90
<i>rho</i>	R	r	100
<i>sigma</i>	S	s	200
<i>tau</i>	T	t	300
<i>upsilon</i>	U	u	400
<i>phi</i>	F	f	500
<i>chi</i>	C	c	600
<i>psi</i>	Y	y	700
<i>omega</i>	W	w	800
<i>sampi</i>	-	-	900

This transliteration scheme differs from the *Thesaurus Linguae Graecae* Project's beta code, in which C = *xi* and X = *chi*.

Fig. 2: Specialised tags

[ut]É[/ut]	uncertain text: could be one of a handful of letters
[rt]É[/rt]	reconstructed text: missing, or could be any letter
[st]É[/st]	superscript text: allows isolation for line length counts
[it]É[/it]	inserted text: often associated with scribal insertion symbols
[kc]É[/kc]	KAI compendium
[sc]É[/sc]	scribal contraction, as listed in Gardthausen
[ns]É[/ns]	<i>nomen sacrum</i> contraction and superscript line
[fn]É[/fn]	final <i>nu</i> superscript line
[di]É[/di]	diaeresis
[rb]É[/rb]	rough breathing
[sb]É[/sb]	smooth breathing
[c0]É[/c0]	correction by original scribe
[c1]É[/c1]	correction by first corrector
[c2]É[/c2]	correction by second corrector
É	
[cx]É[/cx]	correction by unidentified corrector
[d0]É[/d0]	deletion by original scribe
[d1]É[/d1]	deletion by first corrector
[d2]É[/d2]	deletion by second corrector
É	
[dx]É[/dx]	deletion by unidentified corrector

References

- Aland, Kurt, Matthew Black, Carlo M. Martini, Bruce M. Metzger, and Allen Wikgren (eds.). 1983. *The Greek New Testament*. United Bible Societies, 3rd corr. ed. New York: United Bible Societies.
- Contemporary English Version*. 1995. Canberra: The Bible Society in Australia.
- Finney, T. J. 1994. 'A proposed reconstruction of Hebrews 7.28a in P46'. *New Testament studies* 40, 472-473.
- Gardthausen, V. 1913. *Griechische Palaeographie*. Vol. 2. *Die Schrift, Unterschriften und Chronologie im Alterum und im Byzantinischen Mittelalter*. 2nd ed. Leipzig: Veit. Repr. 1978. Berlin: Nationales Druckhaus.
- Kenyon, Frederic G. (ed.). 1936. *The Chester Beatty biblical papyri: descriptions and texts of twelve manuscripts on papyrus of the Greek Bible*. Fasciculus 3 supplement. *Pauline epistles: text*. London: Emery Walker.
- Kenyon, Frederic G. (ed.). 1937. *The Chester Beatty biblical papyri: descriptions and texts of twelve manuscripts on papyrus of the Greek Bible*. Fasciculus 3 supplement. *Pauline epistles: plates*. London: Emery Walker.
- Plotkin, Wendy and C. M. Sperberg-McQueen. 1996. *Text encoding initiative*. WWW document (<http://www.uic.edu/orgs/tei>).
- Robinson, Peter M. W. 1994a. *The transcription of primary textual sources using SGML*. Office for Humanities Communication publications, 6. Oxford: Office for Humanities Communication.
- Robinson, Peter M. W. 1994b. *Collate: interactive collation of large textual traditions, version 2*. Computer program. Oxford: Oxford University Centre for Humanities Computing.

Robinson, Peter M. W. 1994c. *Collate 2: a user guide*. Oxford: The Computers and Variant Texts Project.

TEI classical Greek supplemental to ISOgrk1 and ISOgrk2. 1992. FTP archive (<ftp://ftp-tei.uic.edu/pub/tei/dtd/teigrk.ent>).

COLLATION

Synopsis

Collation is a process employed to compare manuscript texts. This chapter relates to the use of computer-assisted collation methods. Dr. Peter Robinson's *Collate 2* is shown to be capable of producing an elegant output from my transcriptions, provided that they have been preprocessed to discard extraneous information and to separate scribe-specific versions of the transcriptions.

The desire to investigate various aspects of the transcribed texts led me to write a suite of programs in order to produce matrices of data suitable for multivariate analysis. These programs incorporate a number of novel concepts, such as the production of a synthetic text that forms the basis of output data matrices.

The rearrangement of input transcriptions required in order to produce useful output suggests a number of improvements to the way in which they are transcribed in the first place. Consequently, transcription is revisited at the end of this chapter.

Definition and purposes

Collation is essential if relationships between manuscript texts are to be explored. Metzger (1981, 52) gives the following definition and some advantages of collation:

To collate is to compare the text of the manuscript with another text, chosen as standard, and to report each and every difference from the basic text. The advantages of the collation process include (a) the ease with which one can then determine the distinctive elements of the new manuscript, (b) the relatively compact form of the report of those distinctive elements, and (c) the utility of such evidence in preparing a critical apparatus of variant readings.

As implied here, collation may be performed for a variety of reasons. One is characterisation, in which the purpose is to isolate distinctive elements of the manuscript text. Another is efficient presentation of evidence: the enormity of the New Testament textual tradition calls for a convenient and compact means of storing variation data. The purpose of collation may be to construct a critical apparatus. In this case, the collation format is likely to be influenced by the desired arrangement of the apparatus. Yet another purpose of collation is to construct a basis for comparison of manuscript texts.

In the past, collations have necessarily been print-based, employing a printed edition and being recorded with ink on paper. Now the advent of computers has introduced new possibilities. The fundamental task of comparing two texts is readily performed once they have been entered as machine-readable texts. Since a computer screen can display a multitude of images, whereas paper can display but one, there is no longer such a need for compact presentation of texts. Nevertheless, efficient storage remains a virtue in the computer paradigm, and much space is saved by storing manuscript texts as variations from a standard text rather than as complete transcriptions. The wide-spread availability of computer resources has made complex statistical procedures for textual characterisation and comparison accessible to textual researchers. The basic data for these multivariate analysis techniques are, effectively, collations.

Method

The traditional approach to collation involves choosing a well-known edition as the standard or base text against which to compare a manuscript text. The *Textus Receptus* was the universally accepted base text until the twentieth century, but now other standard editions such as Westcott and Hort or the United Bible Societies *Greek New Testament* are likely to be used for the purpose. This lack of a standard collation base has the potential to create difficulty as two manuscript texts recorded by collation cannot be directly compared if they have different base texts.

In the computer context, it is appropriate to retain the traditional form of collation if traditional objectives, including the construction of a critical apparatus, are in mind. However, if the desired outcome is a statistical comparison of texts, it is worthwhile to search for a computer-assisted collation method that is better adapted to the task. What follows is a practical account of two different computer-collation methods, one suited to the production of a critical apparatus, the other custom-designed to produce output suitable for subsequent multivariate analysis.

Peter Robinson's *Collate 2*

Dr Peter Robinson's *Collate 2* is a powerful and flexible program that is capable of producing output in a number of useful formats, one of which is the familiar base text *lemma* versus manuscript text reading layout of conventional collations. It is capable of including up to one hundred texts for collation against any chosen base text. Once instructed as to which manuscript texts to include, *Collate 2* will process them automatically. Among numerous facilities are interactive collation, where output can be adjusted to the editor's preferences; inclusion, exclusion, or separate collation of punctuation; production of an apparatus according to a preset or customised format; regularisation, also known as normalisation, in which spelling variants are levelled; and linearised output that lines up manuscript texts under the chosen base text for ease of visual comparison.

Preprocessing transcriptions

In most cases, the normalisation facilities of *Collate 2* will allow an adequate output to be produced. My transcriptions, however, include differing levels of certainty and telescope the texts of multiple correctors into a single text. This practice makes it impossible for *Collate 2* to produce a clear output unless the corrector and certainty dimensions of the data are discarded by normalisation, a process which is exceedingly tedious for sizeable transcriptions. To illustrate the problem, here is the output from *Collate 2* for Hebrews 2.18 using my transcriptions of P46 and U1, with the United Bible Societies' 4th edition of the *Greek New Testament* chosen as the base text. (Due to formatting constraints, I have used a Roman font to represent printouts from *Collate 2*. There is nothing to stop a Greek font being used under normal circumstances.)

```
<ch 2><v 18>
ubs4    EN W GAR PEPONQEN
p46      GAR [dx]PE[ut]P[/ut]OQ[fn]E[/fn][dx] [cx]PE[ut]P[/ut]O
[st][ut]N[/ut][st]Q[fn]E[/fn][cx]
u1      PEPONQ[fn]E[/fn]

ubs4    AUTOS                PEIRASQEIS                DUNATAI TOIS
p46    AUTOS                PEIRASQEIS
u1      [c2][it]PIRASQIS[/it][c2]

ubs4    PEIRAZOMENOIS        BOHQHSAI
p46    PEI[ut]RA[/ut]ZOMENOIS BOHQ[ut]H[/ut]SAI
u1      PIRAZOMENOIS
```

The information concerning corrections and uncertain text make the output difficult to interpret. Tags for final *nu* abbreviation, superscript text, and inserted text compound the problem. By contrast, the output is easier to understand when preprocessed transcriptions are fed in:

```
<ch 2><v 18>
ubs4    EN W GAR PEPONQEN AUTOS    PEIRASQEIS                DUNATAI TOIS
p46      PEPONQEN
p46x     PEPONQEN
u1      [*****]
u1b     PIRASQIS

ubs4    PEIRAZOMENOIS BOHQHSAI
p46    PEIRAZOMENOIS BOHQHSAI
p46x    PEIRAZOMENOIS BOHQHSAI
u1      PIRAZOMENOIS
u1b     PIRAZOMENOIS
```

Collate 2 was set to write a lineated apparatus, ignore punctuation, and print variations from the base text only. Therefore, nothing appears

where there is no variation from the base text. The asterices enclosed by square brackets mark an omission. Identical settings were used to generate both these outputs: only the input transcriptions were different. This demonstrates the value of preprocessing information-rich transcriptions before collation.

Prep: a preprocessing program

I wrote a preprocessing program to prepare my transcriptions for collation with *Collate 2*. The program is named *prep* and is written in the C programming language. *Collate 2* can perform some of its functions, such as regular substitution of one string by another. A word processor could do the same. Neither, however, could perform its specialist functions of separately treating correctors and uncertainty levels.

Prep starts by checking for tag errors, which is necessary because incorrect tag entry is the transcription sin which doth so easily beset us. To show that this is so, here is a transcribed word containing a tag error:

```
[cx]PE[ut]P[/ut]O[st][ut]N[/ut][st]Q[fn]E[/fn][[/cx]
```

The problem lies in there being two opening superscript text tags, [st]É[st], instead of matching opening and closing tags, [st]É[/st].

Following the tag error check, *prep* makes appropriate alterations to the transcription according to the tagging. Tags such as those marking superscript text, inserted text, diaeresis, breathing, scribal contraction, and *nomina sacra*, are removed. If the collation is to be used to find correlation between manuscript texts for one of these tagged characteristics, the corresponding tags should be retained. In the present case, where the objective is an elegant output, all such tags are removed. Substitutions are made for *kaiv* compendia ([kc]K[/kc] -> KAI) and final *nu* abbreviations (e.g., É[fn]E[/fn] -> ÉEN).

Text tagged as uncertain is changed to lower case, and text tagged as reconstructed is replaced with underscores. This step makes some transcription precautions necessary. Tags which are yet to be processed, such as corrector and deleter tags, must never be enclosed by text tagged as reconstructed. Otherwise, they will be replaced by underscores and

subsequent steps of the program will malfunction, as the following example shows. A word which is partially reconstructed and has been corrected could be tagged as follows:

[rt][c1]RECON[/rt]STRUCTED[/c1]

This would be transformed to:

_____STRUCTED[/c1]

The [c1] tag would be changed to underscores along with the enclosed letters. Consequently, the correction would not be separated out. Happily, a check for persistent tags, which occurs at the end of the program, would bring attention to the problem because of the remaining [/c1] tag.

This problem would not happen if the opening corrector tag preceded the reconstructed text:

[c1][rt]RECON[/rt]STRUCTED[/c1]

The information encoded would be exactly the same; only the order of precedence for tagging would be changed.

After dealing with certainty levels, *prep* divides the input transcription into a set of output transcriptions, with one transcription for each of the manuscript's scribes. The uncorrected original is generated first by reinstating deletions by the original scribe (text enclosed by [d0]...[/d0] tags) and ignoring all other deletions and corrections. Next, the corrected original is generated by including deletions *and* corrections by the original scribe (text enclosed by [d0]...[/d0] or [c0]...[/c0] tags) and ignoring all other deletions and corrections. The process continues up the chain of correctors, until the final separation of unassigned deletions and corrections ([dx]...[/dx], [cx]...[/cx]). Unassigned alterations are treated as having been due to a single scribe (corrector 'x') who is made last in the sequence of correctors.

The corrected original is generated for all verses ('blocks' in the terminology of *Collate 2*). The other scribe-specific transcriptions are

only generated for those verses in which the corresponding scribe has made an alteration. As *Collate 2* only processes witnesses where they are extant, this strategy produces a far more economical output which is still comprehensive. In the case of the papyrus and uncial manuscripts of Hebrews, typically less than twenty lines of variant text for each line of base text are printed. By contrast, about one hundred lines per line of base text would be required if a separate line was devoted to each scribe-specific transcript, regardless of its extent.

Finally, *prep* checks the separated texts for persistent tags. Blocks containing tag errors or persistent tags are written to an error file as a reference for correcting the transcriptions.

The part of *prep* which deals with unwanted tags (the 'detag' function) may be customised to suit other transcription projects. Up to seven correctors besides the original and unidentified correctors can be handled by using numbers in correction and deletion tags. A larger number of correctors can be dealt with by using letters (e.g., [ca]...[/ca] instead of [c0]...[/c0]).

Collation with Collate 2

Once the scribe-specific transcriptions have been generated, all that remains is to feed them into *Collate 2*. After the right settings have been chosen, we can specify a verse and watch as a complete collation of the transcribed manuscripts is printed out before our eyes!

```
<ch 7><v 28>
ubs4 0 NOMOS GAR ANQRWPOUS KAQISTHSIN ARCIEREIS ECONTAS ASQENEIAN
p46  NOMO_  _____pOUS I_____
u1
u2 ANOUS
u3
u6 [*****] IEREIS ANQRWPOUS ECONTAS
ASQENIAN
u6x KAQISTHSIN ARCIEREIS ANQRWPOUS
u16 0 ANOUS __REIS ASQENIAN
u18 ANOUS
u20 ANOUS
u25 ANOUS ASQENIAN
u44 ANOUS
u56 ANOUS ARCIEREIS
u75 ANOUS
u150 KAQ ISTHSIN ASQENIAN
u151
tr
```

The wording of P46 is probably O NOMOS GAR KAQISTHSIN

ANQRWPOUS IEREIS. When compared with the base text, ANQRWPOUS and KAQISTHSIN are transposed, and IEREIS occurs in the place of ARCIEREIS. This is adequately reflected in the collation output, even though part of the phrase is reconstructed text that is printed as underscores. The contraction from ANQRWPOUS to ANOUS, spelling variants, transpositions, omissions, and instances of agreement are all clearly visible. Uncertain text is printed in lower case and appears in the output as a variation. This is appropriate because a collation should highlight questionable text, a function performed by *vid* in conventional transcriptions.

Part of the tuning required for a printout of the kind shown above concerns the font. The one used here consists of Greek upper case letters, which I based on the writing of P13 and P46, and Roman lower case letters. It allows anything that needs to be displayed in Roman letters to be shown as such, provided that lower case letters are used. If a purely Greek font were used, confusion might be caused by sigla appearing in Greek letters. On the other hand, uncertain letters would appear as lower case Greek, which is better than the lower case Roman that *prep* and my font combine to produce. It is important to note that the font is non-proportional; i.e., each character has the same width. Without this characteristic, lineated output from *Collate 2* would fail to line up. I named the font 'nu', which stands for non-proportional uncial.

The preceding outline shows that it is possible for *Collate 2* to produce a useful collation from significantly marked-up transcriptions of Greek New Testament manuscripts provided that they have been preprocessed. After the necessary setting up and normalisation has been performed within *Collate 2*, a clear survey of variation can be generated readily. This approach has potential to advance the quest for a comprehensive critical edition, if only the transcription footwork can be done.

Collation based on a synthetic text

My desire to investigate various aspects of relationships among the transcribed manuscripts led me to invent a method of collation that is based on a synthetic text rather than a standard text. The synthetic text is a universal sequence of words that contains every sequence of words

found in the manuscript texts. It stands at the heart of a suite of PERL programs that I wrote to transform my transcriptions into matrices of data suitable for multivariate analysis.

PERL was selected due to its well-deserved reputation as an easy-to-use text processing language. In many ways, my programs are conceptual children of Dr Robinson's *Collate 2*. Nevertheless, they incorporate novel methods such as separating manuscript texts into a set of scribe-specific texts; using probability to cope with uncertainty; global normalisation (although this is inferior to the local normalisation that can be performed by *Collate 2*); generation of a synthetic text as a basis for collation; and presenting collation output as scribe-specific data matrices. A new version of *Collate* can produce data matrices as well, but only for textual and not orthographic variation.

The programs are modular in the sense that each one reads input files found in its input directory, processes them, then writes corresponding output files to an output directory. The input directory of the next program in sequence is the output directory of the previous program, and so the final output is reached through a chain of individually run programs. Each program has a similar initial structure, with user specifications such as input and output directories being set in the first part of the program listing. The programs must be edited in order to change specifications. This might intimidate those with little programming experience, but it is not difficult in practice. All that is required is to keep a copy of the original program in a safe place in case editing goes awry.

It is important to note that the programs assume that input and output directories reside in the same directory as the programs themselves. Once a program is run, it prints out the user specifications before processing any files from the input directory. As subsequent programs use the output of previous programs, the input directories of previous programs can, with some exceptions, be deleted if desired. Otherwise they will use up space unnecessarily.

A modular approach was adopted because of the enormity of the programming task. I think of the separate programs as akin to the water-

tight compartments of the *Titanic*. In theory, at least, each lives or dies to itself. If one malfunctions then it is relatively simple to isolate the bug and eradicate it. Each one has a well-defined input and output format, which is an advantage of the object-oriented programming philosophy. I had attempted to write a program (in C) which did everything from start to finish within one structure. However, it became so massive that I could not keep track of all its facets as it evolved.

Each program of the suite is described in detail below. Before the 'travelogue' begins, however, it will be useful for the reader to have an overview of the 'itinerary'. Firstly, the transcriptions are filtered to remove elements which are not required in the ultimate analysis. This is not to say that such features are worthless, merely that they are not among the ones I have chosen for analysis. Next, the transcriptions are separated according to their scribes, thereby multiplying the number of texts. At this point, the texts are rearranged into a parallel format so that certainty information appears alongside each word. Now the texts are normalised, with certainty information retained, so that they are directly comparable. A single synthetic text is then constructed from each component text. It forms the foundation upon which to build a set of scribe-specific data matrices for later multivariate analysis. The final program produces a complete and reasonably compact report of the texts of each manuscript's scribes.

Filter

The first of the suite of programs is entitled *Filter*. It takes a set of transcriptions residing in the specified input directory and removes features such as unwanted tags, comments, division markers, and exotic characters by means of deletion or substitution. The resultant texts are written to files with the same names as the input files (i.e., the transcriptions) in the output directory, which is also specified by the user.

Input and output directories are named at the following lines:

```
# Name directories

$InputDirectory = 'Transcribed';
$OutputDirectory = 'Filtered';
```

Here, the input directory has been named *Transcribed*, and the output directory *Filtered*.

Items to be discarded, along with their delimiting characters, are given in the following lines:

```
# Specify delimiters bracketing text to be discarded

@Delimiters = (
    '{', '}',
    '|', '|'
);
```

With these specifications, the program will discard any text that occurs between the delimiters {É} and |É|, as well as the delimiters themselves.

Next, substitutions are set out:

```
# Specify substitutions

@Substitutions = (
    '[/fn]', 'N',
    '[di]I[/di]', 'J',
    '[di]U[/di]', 'V',
    '[di]UI[/di]', 'VJ',
);
```

For each pair, *Filter* will replace the first string of characters with the second string. Given this set of instructions, any occurrence of [/fn] (standing for a final *nu* superscript) will be replaced with N, any occurrence of [di]I[/di] (which stands for *iota* with diaeresis) will be replaced with J, and so on.

Lastly, the user sets out individual items to be discarded:

```
# Specify items to be discarded

@Items = (
    '[st]', '[/st]', '[it]', '[/it]', '[kc]', '[/kc]',
    '[sc]', '[/sc]', '[ns]', '[/ns]', '[fn]', '[/fn]',
    '[rb]', '[/rb]', '[sb]', '[/sb]', '[di]', '[/di]'
);
```

With these specifications, *Filter* deletes tags relating to superscript text, inserted text, *kaiv* compendia, scribal contractions, *nomina sacra* superscripts, and so on. As mentioned before, the fact that I discard these features does not imply that they are insignificant. Rather, it means that subsequent programs in the suite are not equipped to deal with them in an intelligent manner.

The effect of running a transcription through *Filter* is shown below:

Input: *P46*, Heb 1.1 (read from directory *Transcribed*)

```
<ch 1><v 1> {inscription: PROS EBRAIOUS} |f 21r||l 2| POLUMERWS  
KAI POLUTROPWS  
PALAI O [ns]QS[/ns] LALHSAS TOIS PATRASIN [c1][st]HMWN[/st]/[c1] EN  
TOIS PROFHTAISÉ
```

Output: *P46*, Heb 1.1 (written to directory *Filtered*)

```
<ch 1><v 1> POLUMERWS KAI POLUTROPWS  
PALAI O QS LALHSAS TOIS PATRASIN [c1]HMWN[/c1] EN  
TOIS PROFHTAISÉ
```

Separate

Once filtered, separate scribe-specific texts are generated from the transcriptions by a program named *Separate*, which works as described in section 4.3.2, above. User specifications are limited to stating directories and characters used to delimit alteration tags and divisions (i.e., verses):

```
# Name directories  
  
$InputDirectory = 'Filtered';  
$OutputDirectory = 'Separated';  
  
# Specify division marker delimiters  
  
@Division = (  
    '<',    # Open delimiter  
    '>',    # Close delimiter  
);  
  
# Specify tag delimiters
```

```
@Tag = (
    '[' ,      # Start-tag open delimiter
    '[' / ,    # End-tag open delimiter
    'd' ,      # Deletion code
    'c' ,      # Insertion code
    ']'        # Tag close delimiter
);
```

Separate generates a number of output files for every input file, the number depending on how many scribes are identified in the corresponding transcription:

Input: *P46*, Heb 1.1 (read from directory *Filtered*)

```
<ch 1><v 1> POLUMERWS KAI POLUTROPWS
PALAI O QS LALHSAS TOIS PATRASIN [c1]HMWN[/c1] EN
TOIS PROFHTAISÉ
```

Output:

P46, Heb 1.1 (written to directory *Separated*)

```
<ch 1><v 1> POLUMERWS KAI POLUTROPWS
PALAI O QS LALHSAS TOIS PATRASIN EN
TOIS PROFHTAISÉ
```

P46-1, Heb 1.1 (written to directory *Separated*)

```
<ch 1><v 1> POLUMERWS KAI POLUTROPWS
PALAI O QS LALHSAS TOIS PATRASIN HMWN EN
TOIS PROFHTAISÉ
```

Notice that HMWN, which was added by the first corrector, is absent from the separated text corresponding to the original scribe (named *P46*), but present in the text corresponding to the first corrector (named *P46-1*)

Format

A program named *Format* rearranges the separated transcriptions to incorporate certainty information in a format suitable for subsequent processing. Besides specifying input and output directories, division markers, and tag delimiters, the user supplies information concerning certainties, concatenation, line division, and punctuation:

```
# Specify certainty tag generic identifiers
```

```
@Certainties = (  
    'ut',    # Uncertain text  
    'rt'     # Reconstructed text  
);
```

```
# Specify corresponding certainties
```

```
$Uncertain = 0.5;  
$Reconstructed = 0.05;
```

The program assumes that the transcriptions contain three levels of certainty: certain text, which is not tagged; uncertain text, which is subject to some doubt; and reconstructed text, which is very doubtful. These specifications tell the computer what to look for in order to identify uncertain or reconstructed text, and what probability levels to assign to letters within text that is so marked. I use a value of 1/2 (0.5) for uncertain text, which means that I interpret an uncertain letter as one which could be one of two possible letters. In the same way, my value of 1/20 (0.05) for a reconstructed letter means that I regard it as so doubtful that it could be virtually any letter.

```
# Specify concatenation marker
```

```
$Concatenation = '=';
```

```
# Specify newline character and punctuation.
```

```
$NewLine = '|';
```

```
@Punctuation = (  
    ".", "3", "ü", " ", "2", ":", "É", "'", "-",  
    "+", "|"  
);
```

The concatenation marker identifies where a word is divided between consecutive lines of a manuscript. It is given here so that the program can reconstitute split words. The transcriptions themselves use 'newlines' to mark line division. ('Newline' is a programming term that refers to the character or characters that an operating system uses to represent a carriage-return plus a line-feed.) In the rearranged format, newlines are required to divide lines devoted to individual words, punctuation marks, and other such distinct items. For this reason, a character which is not

used elsewhere must be specified as a line-division marker so that information concerning line division can be retained for further analysis. An exhaustive list of punctuation marks found in the manuscript transcriptions is also given so that *Format* can separate words from punctuation marks which immediately follow without an intervening space.

```
# Specify whether to include newline and punctuation
characters.
```

```
# 0 = no, 1 = yes.
```

```
$IncNewLines = 1;
```

```
$IncPunctuation = 1;
```

There are two 'switches' at this point, so called because they have 'on' and 'off' states. Information which is not relevant to a particular analysis can be excluded from the output by setting the relevant switch to 'zero'.

With these settings, the program has the following effect. A transcription of P12 which has already been filtered and separated is introduced here as it contains certainty information:

Input: *P12*, Heb 1.1 (read from directory *Separated*)

```
<ch 1><v 1> POLVMERWS û POL[ut]U[/ut][rt]TRO[/rt][ut]P[/ut]WS
PALE O [ut]Q[/ut]S LALH[ut]S[/ut][rt]AS TOIS P[/rt][ut]A[/ut]TRA=
[rt]SIN HMW[/rt][ut]N EN[/ut] TOIS PR[ut]O[/ut][rt]F[/rt][ut]HTA[/ut][rt]I[/rt][ut]S
[/ut]
```

Output: *P12*, Heb 1.1 (written to directory *Formatted*)

```
<ch 1><v 1>
POLVMERWS 1.000
û          1.000
POLUTROPWS0.615
|          1.000
PALE       1.000
O          1.000
QS         0.750
LALHSAS    0.657
TOIS       0.050
```

PATRASIN	0.462
HMWN	0.163
EN	0.500
TOIS	1.000
PROFHTAIS	0.511
	1.000

The certainties are calculated on a letter-by-letter basis. To illustrate, the input transcription has, in effect, [rt]HMW[/rt][ut]N[/ut]. Each of the three reconstructed letters are assigned a probability of 0.05, while the one uncertain letter is assigned a value of 0.5. The overall certainty for the word is then $(0.05 + 0.05 + 0.05 + 0.5) / 4 = 0.163$.

Normalise

Normalise is designed to replace scribal forms of words found in the manuscript transcriptions with standard forms which have a conventional orthography, thereby allowing words which are equivalent to be recognised as such by simple comparison. The program refers to a table of equivalents to determine replacements for the scribal forms. In the case of the manuscripts of Hebrews transcribed for this thesis, the table comprises approximately 2000 lines, each containing a scribal form, its standard equivalent, and descriptions of the nature of the scribal forms. This equivalents table took months to construct because each scribal form had to be considered individually in order to decide whether it was a spelling or a textual variation. The table itself is found on the data disks at the end of the thesis. The associated notes, which give reasons for decisions in all but straightforward cases, run to 75 pages and are found in appendix 3.

Besides input and output directories, the user must specify the directory which contains the equivalents table file, and the file's name:

```
# Name directories

$InputDirectory = 'Formatted';
$TableDirectory = 'Equivalents';
$OutputDirectory = 'Normalised';

# Name equivalents table
```

```
$TableName = 'Hebrews';
```

Division (i.e., verse) markers, newline characters, and special characters to be treated as normal letters, such as the question mark for unreadable letters and the *kaiv* compendium character, must also be specified so that the program can function correctly.

The following input and output shows the effect of *Normalise* on the transcription of P12:

Input: *P12*, Heb 1.1 (read from directory *Formatted*)

```
<ch 1><v 1>
POLVMERWS 1.000
û          1.000
POLUTROPWS0.615
|          1.000
PALE       1.000
O          1.000
QS         0.750
LALHSAS    0.657
TOIS       0.050
PATRASIN   0.462
HMWN       0.163
EN         0.500
TOIS       1.000
PROFHTAIS  0.511
|          1.000
```

Output: *P12*, Heb 1.1 (written to directory *Normalised*)

```
<ch 1><v 1>
POLUMERWS 1.000
KAI        1.000
POLUTROPWS0.615
|          1.000
PALAI      1.000
O          1.000
QEOS       0.750
```


LALHSAS	0.657
TOIS	0.050
PATRASIN	0.462
HMWN	0.163
EN	0.500
TOIS	1.000
PROFHTAIS	0.511
	1.000

The certainties remain the same as they relate to the status of the scribal forms and not their standard equivalents. Besides simply replacing a word with its specified equivalent, the program can replace a sequence of scribal forms with a sequence of standard forms (e.g., POLVMERWS û POLUTROPWS -> POLUMERWS KAI POLUTROPWS), even if newline characters occur within the sequences.

Synthesise

The heart of the novel method implemented in these programs is found here. *Synthesise* generates a universal sequence which contains every sequence of words, punctuation, division markers, and newline characters contained in the input transcriptions. The resultant synthetic text is not like a conventional text which makes sense to read. Rather, it contains every readable text.

Such a sequence could be generated simply by joining each manuscript text together, but a more efficient sequence would be better. To illustrate, consider two sequences which must be combined into a sequence from which either can be extracted:

Sequence 1: A B C D E F G

Sequence 2: A B D C E F G

Joining the two sequences results in one from which either can be extracted by choosing sequential elements:

Synthesis: A B C D E F G A B D C E F G

A more efficient synthesis satisfies the same requirement, and is clearly a

better use of space:

Synthesis: A B D C D E F G

I invented an algorithm to create compact sequences of this kind. It takes a primary and secondary sequence and creates a synthesis from them in the manner outlined below:

(1) An initial primary sequence of zero or more elements and the initial secondary sequence element are split off at a barrier. The barrier is defined by corresponding elements in the primary and secondary sequences. The barrier element is the first secondary sequence element after the initial secondary sequence element which has a corresponding element in the primary sequence.

(2) If the initial secondary sequence element is matched by an element of the initial primary sequence then the following actions occur:

- (a) the initial primary sequence up to, but not including, the matching element is appended to the synthesis;
- (b) the matching element and any part appended to the synthesis are discarded from the initial primary sequence; and
- (c) the initial secondary sequence element is appended to the synthesis.

(3) What is left of the initial primary sequence is joined back to the beginning of the primary sequence, and the process begins again with the remaining primary and secondary sequences.

The algorithm finishes by appending any remnants of the primary and secondary sequences to the synthesis once a barrier element cannot be found.

The printout of fig. 1. is given to illustrate the algorithm's operation upon the sequences given above. The arrow (->) signifies addition of an element to the synthesis, while 'match' refers to the barrier element.

This is not the only algorithm that will produce a universal sequence from a set of component sequences. It works quite well because of the barrier feature which helps prevent repetition of sequences due to

frequently occurring words such as KAI. Even with this feature, I have noticed that it can produce inefficient (i.e., repetitive) sequences in the presence of very frequently recurring items such as newline characters and punctuation.

Once the usual specifications have been entered, *Synthesise* produces the following output from a set of transcriptions of Heb 1.2:

```
<ch 1><v 2>  
EP  
ESCATOU  
TWN  
HMERWN  
TOUTWN  
ELALHSEN  
KAI  
HMIN  
EN  
UIW  
ON  
EQHKEN  
KLHRONOMON  
PANTWN  
DI  
OU  
KAI  
EPOIHSEN  
TOUS  
AIWNAS  
EPOIHSEN
```

The texts of manuscripts P46, U1, U2, U3, and U6 are contained here. One manuscript adds KAI after ELALHSEN. Another omits KAI before EPOIHSEN. A transposition of TOUS AIWNAS EPOIHSEN also occurs. All of these variations are represented by marking presence or absence of sequential words in this synthetic text.

Matrix

A major objective of collation in this thesis is to produce data matrices for multivariate analysis. *Matrix* generates a separate data matrix for each scribe identified in the input transcriptions. The matrix devoted to a particular scribe is only produced for the verses in which that scribe has been active. It includes the testimony of any other scribal text which exists for all of the same verses.

The program allows many different perspectives of the input data to be extracted. Output is formatted as rows of ones and zeroes which signify presence or absence of the corresponding word, punctuation mark, or newline character of the synthetic text upon which it is based. Each column represents a different witness. The program includes the facility to exclude unwanted words, punctuation, and so on, from being reported in the output. In this way, the scope of the data matrices can be restricted to textual variation, spelling variation, or punctuation alone. The directories and file names of the unwanted items file and synthetic text file are specified in the following part of the program:

```
# Name directories

$InputDirectory = 'Normalised';
$SynthDirectory = 'Synthesised';
$UnwantedDirectory = 'Equivalents';
$OutputDirectory = 'Matrices';

# Name files

$SynthName = 'Synthesis';
$UnwantedName = 'Unwanted';
```

Items such as words and punctuation marks are classified as missing data if they have certainties which fall below a threshold value. These items are marked by a 'negative one' in the data matrices. With the following setting, any reconstructed text in the original transcriptions is deemed to be missing, while certain and uncertain text is deemed to be present:

```
# Set threshold. Any item with a certainty below the
# threshold will be classified as a missing datum.

$Threshold = 0.5;
```

An absent item is classified as missing if it is preceded by missing data. This avoids an illusion of certainty of absence that can occur with reconstructed text. Suppose that a manuscript has a lacuna that does not appear to be able to accommodate the expected text. An editor may provide a suggested reconstruction with one of the usual words omitted. Once presented as part of a data matrix based on a synthetic text, a decision must be made concerning how to treat the certainty of the apparently absent item. If the item is marked as definitely absent, a higher certainty is implied than is justified by its context. A more prudent approach classifies the apparently absent item as missing or not missing according to the certainty of the item which precedes it in the manuscript.

Matrix allows the output to be formatted in various ways. Row and column labels, division markers, rows with singleton variations (i.e., variations in which only one witness differs from the rest), rows in which no variation occurs, and rows with missing data are all able to be included or excluded as desired.

Specify which features to include. 0 = no, 1 = yes.

```
$IncLabels = 1;          # Row and column labels
$IncDivs = 1;            # Division markers
$IncSingles = 1;        # Singleton variations
$IncNoVars = 1;         # Rows with no variation
$IncMissing = 1;        # Rows with missing data
```

If the output is destined for multivariate analysis, all of the switches should be set to 'zero' for the following reasons. Rows with singleton variation and rows without variation have no value in establishing relationships between witnesses. Rows with missing data are capable of adversely affecting dissimilarity matrices constructed during the multivariate analysis procedure. Also, multivariate analysis software can only be expected to accept matrices of numbers, so labels and division markers must be excluded. The analysis software should, however, accept files that specify labels. To accommodate these requirements, *Matrix* generates separate files containing labels for each data matrix if the labels and division-marker switches are set to zero. *Matrix* dimensions are included as well, thereby saving the user the trouble of counting how many rows and columns the matrix contains.

This is the output data matrix for P12 with labels included:

R/C	P12	P46	P46-1	U1	U1-0	U2	U3	U6	UBS4
<ch 1><v 1>									
POLUMERWS	1	1	1	1	1	1	1	1	1
KAI	1	1	1	1	1	1	1	1	1
POLUTROPWS	1	1	1	1	1	1	1	1	1
PALAI	1	1	1	1	1	1	1	1	1
O	1	1	1	1	1	1	1	1	1
QEOS	1	1	1	1	1	1	1	1	1
LALHSAS	1	1	1	1	1	1	1	1	1
TOIS	-1	1	1	1	1	1	1	1	1
???	-1	0	0	1	0	0	0	0	0
PATRASIN	-1	1	1	0	1	1	1	1	1
HMWN	-1	0	1	0	0	0	0	0	0
EN	1	1	1	1	1	1	1	1	1
TOIS	1	1	1	1	1	1	1	1	1
PROFHTAIS	1	1	1	1	1	1	1	1	1

I use the term 'principal witness' to refer to the witness that determines which verses will be included in its associated matrix. In this case, the principal witness is P12, which only exists for Heb 1.1. The other witnesses are those that exist for the same verses as the principal witness. The leftmost column is the synthetic text. The texts of each constituent witness can be reconstructed by interpreting 'one' as presence and 'zero' as absence of the corresponding word. 'Negative one' means that the word has an estimated probability of being present that is less than the specified threshold value. To give an example, the only witness which is certain to have HMWN following PATRASIN is the first corrector of P46 (i.e., P46-1). The word appears to be present in P12 as well, but its poor state of preservation disqualifies it from further consideration.

The data matrix of a more extensively preserved witness will have more rows and, possibly, less columns. The rows are more numerous because there are more words in the collated texts. The number of columns can be less because input witnesses that do not preserve the same verses as the principal witness are excluded. The matrix of U2, for example, covers all

verses of Hebrews but includes only those witnesses which do so as well. Collating the first three verses of Hebrews for the texts of UBS4 and all the scribes and correctors identified in the transcriptions of P46, U1, U2, U3, and U6, results in a matrix that has 70 rows but only six columns. The number of rows is substantially reduced if those with no variation, singleton variations, or missing data are discarded. For Hebrews 1.1-3 and these witnesses, the number of rows falls from 70 to two.

Report

The final program in the suite is named *Report*. It produces a concise summary of constituent scribe-specific texts by reference to the synthetic text, which comprises the first column of the report. Asterices (*) mark presence and dashes (-) mark absence of corresponding words. Question marks (?) identify words classified as missing data.

Before the program is run, the user must supply the usual kinds of information including input, output, and synthetic text directories, synthetic text and output file names, and the missing data certainty threshold.

When supplied with texts derived from transcriptions of P12, P46, U1, U2, U3, U6, and UBS4 for Heb 1.1-3, *Report* gives the output shown in fig. 2. This is essentially the same kind of output as produced by *Matrix*, except that each witness that is extant for a particular verse is included, and the report covers all input verses. By contrast, each data matrix is confined to the verses of a principal witness and a constant set of witnesses that exist for those verses.

Utility programs

The following are descriptions of a set of utility programs I wrote to assist with the process of collation by the foregoing suite of programs. These programs require the user to specify directories, file names, and other parameters in the same manner as outlined in the examples given above.

Checkfinds tagging errors in transcriptions which employ the *Collate* system of mark-up.

Punctuation lists characters in a set of input transcriptions that are suspected of being punctuation marks. Such a list is essential for the correct operation of *Format*.

Tabulate constructs a table of items (that is, words, punctuation marks, and newline characters) that occur in a set of formatted transcriptions but do not occur in a specified standard text. Each record of the table is formatted as follows:

Item TAB Duplicate TAB Blank TAB Location NEWLINE

Such a table provides a good starting point for the equivalents table which is required by *Normalise*. The duplicate is manually replaced with the user-specified equivalent of each item. The blank field is intended to accept a short description of the nature of variation displayed by its item. Descriptions which I used in this field include: variant, for genuine textual variants; terms such as EI/I, AI/E, O/W, *iota* adscript, movable *nu*, contraction, compendium, and punctuation for orthographical variations; numeral, for a letter that represents a number; division, for non-standard word division (e.g., PRO' DROMOS for PRODROMOS); ambiguous, for words such as PÑÑÑÑ and KE that have more than one possible meaning; illegible, for words that can't be read; optional, for an optional spelling (i.e., the lexicon allows more than one form); and spurious, for a scribal form which should be replaced with a standard form but must be left untouched as it is a word in its own right.

I wrote the program *LSI* to list specified items of a table such as just described. Once the equivalents table is complete, this program can be used to generate a list of items which have specified entries in a particular field. It is used to make the unwanted items file used in *Matrix* to exclude the specified items from further consideration. The user specifies search terms (also known as patterns) and a field (which is usually the descriptive field). *LSI* then searches the given field of each table record for the patterns, and adds the corresponding item to the output list if a match is found. The program has a positive and negative mode. If the positive mode is selected, items with matching terms are listed. In the negative mode, every non-matching item is listed.

In addition, I wrote a number of programs to facilitate subsequent analysis.

CT constructs texts from a sample data matrix, variation units key, and a standard text. It is described in detail in the next chapter. The program listing gives instructions concerning formats required for the matrix and key.

Halve discards every second row of a data matrix. It was written to investigate the effect of a decreasing number of matrix rows on multivariate analysis. The program works in an iterative manner so that an input matrix of, say, 500 rows will generate matrices with the following numbers of rows: 250, 125, 63, 32, 16, 8, 4, 2, and 1.

Lastly, *LI* lists items of a formatted witness and counts the total number of certain and uncertain items. By using this program, all of the distinct words of a particular witness can be listed, and its total number of words known. Uncertain items are those with certainties below a specified threshold. Their relative number is an indication of the state of preservation of a given witness.

Producing the output desired

Each program may be run on a Macintosh, PC, or UNIX system once the user has specified the system in the program listing. Some of the programs are very demanding of computer resources. *Matrix*, for example, requires an allocation of over 5 MB of RAM and takes over an hour to run on a UNIX machine if all of the Hebrews transcriptions and associated files are being processed.

Different aspects of the input transcriptions can be extracted by using well-chosen combinations of settings in the collation suite and utility programs. To generate data matrices relating to textual variation alone, *Format* is set to eliminate punctuation and line-divisions. The formatted transcriptions are normalised, then *Synthesise* is set to produce a synthetic text from the normalised witnesses. Before the data matrices are generated, *LSI* is used in conjunction with the equivalents table to construct a list of items which have not been normalised because they are either illegible, ambiguous, or spurious. *Matrix* produces the desired

output with this list as its unwanted items file and the normalised witnesses as input.

To investigate a particular type of spelling variation, punctuation marks and line-divisions are eliminated as before. Normalisation is not employed, and the synthetic text is generated directly from the formatted texts. The equivalents table is still used, but only for the purpose of generating a list of everything but the words exhibiting the spelling variation in question. A list of all words found in the standard text is generated using *LI*, then appended to the other list. The resultant list contains all words in the input transcriptions except for those exhibiting the spelling variation of interest. Finally, *Matrix* is set to process the formatted transcriptions, using the compound list as its unwanted items file.

Punctuation matrices can be generated by including punctuation at the formatting stage, then using the listing utilities and unwanted items file to eliminate everything but punctuation from the output. Matrices devoted to line division can be generated in the same manner.

Transcription revisited

Serial versus parallel representation

During the struggle to compose these programs, a particular strategy was repeatedly helpful: to separate dimensions of the text which have been encoded by serial mark-up into a parallel representation. This approach was the key to successful treatment of scribal alterations and uncertain text. To illustrate, a section of text which has been altered by a scribe and includes letters in various stages of preservation might be transcribed as follows, where d1 means deletion by scribe 1, c1 means correction by the same scribe, and ut stands for uncertain text:

[d1]This is the [ut]original[/ut] text.[/d1] [c1]This is the altered text.[/c1]

The problem with the serial mark-up shown here is that, in the absence of some difficult programming, the idiot savant computer does not realise that [d1]This[/d1] corresponds to [c1]This[/c1], or that [c1]altered[/c1] has replaced [d1][ut]original[/ut][[/d1]]. Once the text is recast in a parallel

fashion, however, it is a simple matter to program the computer to recognise equivalence or difference by restricting its comparison to the scribal texts alone:

<i>Scribe 0</i>	<i>Certainty</i>	<i>Scribe 1</i>	<i>Certainty</i>
This	1.0	This	1.0
is	1.0	is	1.0
the	1.0	the	1.0
original	0.5	altered	1.0
text	1.0	text	1.0
.	1.0	.	1.0

The reduced certainty level indicated by [ut]É[/ut] is translated to a probability of 0.5 in this example. The computer can be instructed to treat text with less than a specified threshold of probability as missing data at the collation stage. In this way, the complicated programming required before a computer can recognise corresponding words of texts that employ serial mark-up is reduced to simple comparison of specified columns of parallel texts.

Normalisation

The same technique facilitates comparison where texts have differing orthography. For example, two analogous Greek texts might appear as follows:

Text 1: Polumerw'" kai; polutrovpw" pavlai oJ qeo;"

Text 2: POLVMERWS K POLUTROPWS PALAI O QÑSÑ

A collation program which does not distinguish between fonts might see the following, depending on the character mapping of the fonts:

Text 1: Polumerw'" kai; polutrovpw" pavlai oJ qeo;"

Text 2: POLVMERWS K POLUTROPWS PALAI O QÑSÑ

Whereas the words are equivalent, the computer would not recognise any as the same. The situation would improve slightly if the difference between upper and lower case were ignored. The words Polumerw'", polutrovpw", and pavlai of the first text would then be recognised as

having more than 50% in common with the corresponding words of the second text. This is still a dismally inaccurate reflection of the actual situation.

Manuscript texts must be normalised to allow direct comparison. Normalisation is the replacement of scribal forms with equivalents that have the orthography of a standard lexicon. It can be achieved by replacing every instance of a particular scribal form with a standard form which is deemed to be its equivalent. The basis of this global replacement strategy is an equivalents table made up of a column of scribal forms found in the manuscripts and a parallel column of specified standard forms:

<i>Scribal</i>	<i>Standard</i>
K	KAI
kai;	KAI
0	0
oJ	0
PALAI	PALAI
pavlai	PALAI
Polumerw'"	POLUMERWS
POLUTROPWS	POLUTROPWS
polutrovpw"	POLUTROPWS
POLVMERWS	POLUMERWS
qeo; "	QEOS
QÑSÑ	QEOS

I used this system in my normalisation program. It is quite easy to implement, but is flawed because it is possible for a scribal form and its standard equivalent to be distinct legal words. (For example, whereas AQETHSEIS at Heb 7.18 in U16 is probably a spelling variation of AQETHSIS, it is a word in its own right.) Therefore, the global replacement strategy has the potential to inadvertently replace valid occurrences of a scribal form with a specified equivalent which is a different word. This possibility was avoided in my programs by not replacing scribal forms so affected. Consequently, these words had to be excluded from consideration at the analysis stage.

Another normalisation strategy which is not subject to this weakness is direct specification of equivalents by means of parallel texts:

<i>Text 1</i>	<i>Equivalent 1</i>	<i>Text 2</i>	<i>Equivalent 2</i>
Polumerw' "	POLUMERWS	POLVMERWS	POLUMERWS
kai;	KAI	K	KAI
polutrovpw"	POLUTROPWS	POLUTROPWS	POLUTROPWS
pavlai	PALAI	PALAI	PALAI
oJ	O	O	O
qeo; "	QEOS	QÑSÑ	QEOS

This method is reliable but demands considerable labour to implement because equivalents must be individually specified for each word of each transcription. Where there are numerous witnesses, the amount of effort can be reduced by setting a computer to supply equivalents for scribal forms that have already been specified in the same chapter and verse of a previous witness. All that then remains is to give equivalents for words and scribal forms which have not been encountered previously.

Dr Robinson's *Collate 2* uses a flexible normalisation system which permits local normalisation for words where there is danger of ambiguity, and global normalisation where there is not. The basis of the system is a dialog box which asks the user to specify the domain of a particular normalisation, or regularisation in *Collate 2* nomenclature. Domains can be all verses of all witnesses (i.e., global), all verses of one witness, or specified verses of one witness. *Collate 2* also employs fuzzy matching, where the computer calculates numerical similarities between a manuscript word and nearby base text words, finding the best match with similarity greater than a certain threshold. These two devices can reduce the number of equivalents that must be specified manually. Unfortunately, the fuzzy-match strategy is hard-pressed to work well in a highly inflected language like Greek. This is because two completely different words with the same prefix or suffix can appear very similar in terms of their number of matching letters.

Other orthographical details can be represented by parallel formatting:

<i>Text 1</i>	<i>Case</i>	<i>Acc.</i>	<i>Contr.</i>	<i>Text 2</i>	<i>Case</i>	<i>Acc.</i>	<i>Contr.</i>

P	u	-	-	P	u	-	-
o	l	-	-	O	u	-	-
l	l	-	-	L	u	-	-
u	l	-	-	V	u	d	-
m	l	-	-	M	u	-	-
e	l	-	-	E	u	-	-
r	l	-	-	R	u	-	-
w'	l	c	-	W	u	-	-
"	l	-	-	S	u	-	-
k	l	-	-	K	u	-	-
a	l	-	-	A	-	-	yes
i;	l	g	-	I	-	-	yes
...							
q	l	-	-	QÑ	u	-	-
e	l	-	-	-	-	-	yes
o;	l	g	-	-	-	-	yes
"	l	-	-	SÑ	u	-	-

Here, 'c' stands for circumflex, 'g' for grave, 'd' for diaeresis, 'l' for lower, and 'u' for upper. Columns could be added for font, breathing, form of *sigma*, form of contraction, *nomina sacra* superscripts, final *nu* abbreviation, or any other feature of interest. Each feature could have a corresponding column to accommodate certainties. To illustrate, if one were not sure whether an accent was grave or acute, either could be entered in the accent column then given a probability of 0.5 in the corresponding certainty column slot. The same applies for letters, where what might be a *kappa* or a *chi*, for example, could be entered as a *kappa* with a certainty of 0.5. Another column might be added to hold the alternative possibility, or possibilities if there were more than two options.

Probabilistic treatment of uncertainty

I define the certainty of a feature as a probability equal to the inverse of the number of states that can reasonably occupy its place. Probabilities for letters range from 1/1 (1.0) if only one letter is a plausible candidate, to about 1/20 (0.05) if the relevant space could have been occupied by

any letter. The lower probability limit is an approximate value which I have chosen in view of the fact that the number of letters which are likely to be encountered in a Greek New Testament manuscript is less than the total number of Greek writing letters, which is 24. (Letters such as *digamma*, *koppa*, *sampi*, and non-Greek letters, are so rare that they have a negligible effect on this average probability of occurrence.)

Such a statement of certainty allows the transcriber to express the degree of doubt with greater accuracy than is possible with the familiar print-based transcription method that is specified in the Leyden conventions. This system employs the sublinear dot for the purpose of indicating doubt. According to Herbert C. Youtie (1966, 251), the meaning of the sublinear dot is not well defined:

What does an editor mean to tell us when he inserts a dot under a letter and so marks it as doubtfully read? May we say that a doubtful letter is a letter of which the transcriber is assuring us that he sees one or more remnants, but these are remnants which he cannot assimilate to any known form of that letter, or perhaps only to any form of the letter as it is written in his document? This is frequently the situation, but often enough the dot marks the presence of a remnant which is simply not characteristic of any one letter and could for this reason be adapted to the shapes of a number of different letters. Long experience of papyrus editions proves that we cannot be sure exactly what kind or degree of doubt an editor intends to express with a dotted letter, but the minimum intention is easy to establish: he is in some way disturbed about his identification of the remnants.

The sublinear dot can also mean 'a condition of severe mutilation where no real doubt is felt' (Youtie, 1974, 54). Its broad range of meanings weakens its usefulness, and calls for a better defined method of indicating certainty. An estimate based on the number of reasonably accessible states is an effective means of expressing degree of doubt, but there are a number of kinds of doubt that require separate treatment. Here, once again, a parallel approach provides a way forward.

The transcriber has to contend with separate dimensions of the same text when trying to decipher doubtful letters. Youtie (1966, 253) writes,

[the one transcribing a text] constantly oscillates between the written text and his mental picture of its meaning, altering his view of one or of both as his expanding knowledge of them seems to make necessary. Only when they at last cover each other is he able to feel that he has solved his problem. The tension between the script and its content is then relaxed: the two have become one.

At the script pole, a letter's remnants are examined to determine what letters might have left them behind, regardless of the surrounding context. (Machine-based optical character recognition systems tend strongly towards this extreme.) At the content pole, the editor is entirely concerned with context and has no regard for the actual ink traces. Here, the choice of letter is a value judgment which requires a strong grasp of the language being read. (This is generally beyond the capabilities of machines.)

The script aspect will suggest a number of letters as being consistent with a letter's remnants, while the content perspective will suggest a range of words that can fit the context. Each dimension can be treated separately, then common ground can be sought in order to produce a reasonable estimate of doubt. The following example serves to illustrate this approach:

The at sat on the mat.

As far as the script perspective is concerned, the doubtful *letter* could be a, b, c, d, e, g, h, n, o, p, q, r, or s. From the content perspective, the doubtful *word* might be bat, cat, fat, hat, mat, oat, pat, rat, and vat. (Strictly speaking, not all of these are capable of sitting.) The two perspectives give probabilities for the doubtful letter of $1/13$ (~ 0.08) and $1/9$ (~ 0.11), respectively. Once the possible states of the two dimensions are compared, the reasonably accessible states in the first dimension are reduced to b, c, h, o, p, and r. At the same time, the states accessible to the second dimension are reduced to bat, cat, hat, oat, pat, and rat. The corresponding certainty, which is now the same for both perspectives, can be expressed as $1/6$ (~ 0.17).

In the event that there is no intersection between the accessible states of

the respective dimensions, an average of the two separate probabilities might be given instead. Whether there are common states or not, the editor must still choose only one state for the transcription. In this example, most editors would choose the letter 'c' due to the familiar ring of the resulting sentence.

This shows that the certainty of a doubtful feature can be estimated in a well defined way by separately counting accessible states from the perspectives of script and content, then taking the inverse of the number of common states. A more advanced variation on the theme would entail assigning individual probabilities to the accessible states according to their expected frequencies. In this case, the certainty of a coincident state would be an average of the corresponding script and content certainties, and a particular state would probably commend itself as more probable than the rest.

While the basic method worked well in the previous example of a single doubtful letter, the number of permutations and combinations that must be considered quickly increases with longer sequences of doubtful letters. A computer could help by comparing all possible words in a language with the possible identities of the letters. This is not a straightforward task because where there is difficulty in deciphering a manuscript, there is often uncertainty concerning the number of doubtful letters that occupy a space. Also, the number of words to be compared is multiplied by inflection and spelling variation.

One possible meaning of the sublinear dot remains to be addressed before leaving the subject of uncertain text: it is sometimes used to indicate mutilation rather than doubt. A parallel representation can make this clear by adding a column that gives an estimate of the amount of a letter that remains. No one who has transcribed a large text would contemplate entering this data on a letter-by-letter basis. However, this is the kind of information that computer-based technology can be expected to generate one day. Another column could be added to indicate presence or absence of writing material where a doubtful letter stands so that the reason for the letter's doubtful status can be better understood. Of course, there is little need for such information if high quality images of the manuscript are readily accessible.

Parallel mark-up

These considerations lead me to suggest that in the context of collation, parallel representation is superior to serial mark-up. A sizeable part of my programming effort went into converting serial transcriptions to parallel forms. Once this was achieved, subsequent processing steps were dramatically simplified. In view of this, it makes sense to avoid serial mark-up altogether and to proceed straight to what might be called parallel mark-up. This is not a new idea: the Computer Assisted Tools for Septuagint Studies project headed by Robert A. Kraft and Emanuel Tov made use of 'vertical texts' and parallel columns to show correspondence of Hebrew and Greek words, among other things (Kraft and Tov, 1986).

Given that the parallel approach is better, it is logical to discuss the characteristics of a transcription tool which implements it. This tool would resemble existing spreadsheets which consist of many cells arranged in columns. However, to carry the requirements of the tool beyond what is normally found in spread sheets, each cell would need the potential to translate its contents into a new parallel representation, perhaps by means of a script that could be run on command. To illustrate with the text given earlier, the first level of the tool would consist of parallel columns to accept scribal and standard forms of manuscript words:

<i>Text</i>	<i>Equivalent</i>
Polumerw'''	POLUMERWS

Each text cell has the potential to generate a new representation of its contents upon demand. Here, the associated script might instruct the computer to generate columns entitled 'text', 'case', 'accent', and 'contraction', then divide the word into individual letters and enter them into the 'text' column. The other cells would then be filled in manually or with computer assistance:

<i>Text</i>
Polumerw'''

↓

<i>Text</i>	<i>Case</i>	<i>Acc.</i>	<i>Contr.</i>
P	u	-	-
o	l	-	-
l	l	-	-
u	l	-	-
m	l	-	-
e	l	-	-
r	l	-	-
w'	l	c	-
"	l	-	-

The same goes for each equivalent cell, but a different structure would probably be specified in the script:

Equivalent

POLUMERWS

↓

<i>Equivalent</i>	<i>Part of speech</i>	<i>Eng. trans.</i>
POLUMERWS	adverb	in many parts

Each cell of each level would have the same ability to generate a new representation by means of a script. For example, the 'part of speech' cell could generate another level to hold further grammatical details.

A transcription tool of this kind would have the advantage of being readily altered if it was decided to add new dimensions, such as certainty columns for selected features. An equivalent alteration would be more difficult in the serial mark-up context as it would normally demand the insertion of additional sets of tags. Another advantage of the parallel approach is that it results in uncluttered representations, thereby reducing the prevalence of certain kinds of transcription errors.

Summary

Computer-assisted collation of New Testament manuscripts has been shown to work. The results are complete and accurate representations of the data. Once adequate preparatory steps have been taken, the programs described in this chapter produce an accurate, complete, and easily

reproducible comparison of input transcriptions.

Dr. Robinson's *Collate 2* is a flexible program that is capable of producing a properly formatted critical edition and apparatus from a set of input transcriptions. The new *Collate 2.1 Project edition* of the program can also produce SGML output, data matrices for multivariate analysis, and matrices suitable for cladistic analysis (i.e., analysis aimed at discovering probable genealogies). *Collate 2* proved able to take preprocessed versions of my transcriptions and produce a lineated output that presents the evidence in a clear manner.

In order to investigate dimensions of the transcriptions which *Collate 2* is not designed to extract, I wrote a suite of programs to produce data matrices for multivariate analysis. These programs rely on the generation of a synthetic text that contains every sequence of items contained in the input transcriptions, and are able to treat varying levels of certainty in an intelligent manner. By suitable manipulation of settings and the use of some utility programs, they can produce data matrices which focus on textual or orthographical aspects of the transcriptions alone.

Processing serial transcriptions requires that their various dimensions be separated at a preliminary stage. A good deal of work could be avoided by making transcriptions in which these dimensions are already separated, a technique which I have described as parallel mark-up to distinguish it from serial mark-up. Another technique discussed relates to certainty within texts. Good science demands good error analysis. Conventional techniques of manuscript transcription include use of a sublinear dot or the abbreviated word *vid.*, neither of which have a well defined meaning. The assignment of probability levels on a letter-by-letter basis provides a more exact approach.

So far, this chapter has not addressed the issue of utility in the use of computers to collate texts. There is no doubt that the probability of certain kinds of collation errors is significantly reduced. Unfortunately, new classes of errors such as programming and logical errors are introduced. Significant time must be devoted to writing the programs, unless one can perform the kind of collation required with a program written by another researcher. Time must also be devoted to supplying

normalisation and other kinds of information to the programs in order to produce sensible output. In my case, transcription time was measured in years, programming time in half years, and normalisation time in months. A theoretical advantage of computer assisted collation is that transcriptions and programs will only have to be made once. In practice, a program's author must constantly revise it to cope with advancing technology, transcription standards, and analysis techniques. These have the common characteristics of perpetual and rapid development.

Fig. 1: Operation of the compact sequence algorithm

```
PS: A B C D E F G
SS: A B D C E F G
Match: B
IPS: A
ISS: A
SS -> A
PS: B C D E F G
SS: B D C E F G
Match: D
IPS: B C
ISS: B
SS -> B
PS: C D E F G
SS: D C E F G
Match: C
IPS:
ISS: D
SS -> D
PS: C D E F G
SS: C E F G
Match: E
IPS: C D
ISS: C
SS -> C
PS: D E F G
SS: E F G
Match: F
IPS: D E
ISS: E
PS -> D
SS -> E
PS: F G
SS: F G
Match: G
IPS: F
ISS: F
SS -> F
PS: G
SS: G
IPS: G
ISS: G
SS -> G
```

(This printout was obtained by reinstating the 'print' statements found in the 'Synthesise' subroutine of the program named *Synthesise*.)

Fig. 2: Output from *Report*

[illegible]

* * * * *

— — — — — *

Output from *Report* (continued)

[illegible]

EN
UYHLOIS

EN
UYHLOIS

References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Borenstein, Philip, and Jeff Matson. 1991. *Think C: user manual*. Cupertino: Symantec.
- Gottfried, Byron S. 1990. *Schaum's outline of theory and problems of programming with C*. Schaum's outline series. New York: McGraw-Hill.
- Hoffman, Paul E. 1997. *Perl 5 for dummies*. Foster City: IDG Books Worldwide.
- Kernighan, Brian W. and Dennis M. Ritchie. 1988. *The C programming language*. 2nd ed. Englewood Cliffs: Prentice Hall.
- Kraft, Robert A., Emanuel Tov, et. al. 1986. *Computer assisted tools for Septuagint studies (CATSS)*. Vol. 1. *Ruth*. Society of Biblical Literature: Septuagint and cognate studies series, 20. Atlanta: Scholars Press.
- Jeff Matson. 1991. *Think C: standard libraries reference*. Cupertino: Symantec.
- Robinson, Peter M. W. 1994b. *Collate: interactive collation of large textual traditions, version 2*. Computer program. Oxford: Oxford University Centre for Humanities Computing.
- Robinson, Peter M. W. 1994c. *Collate 2: a user guide*. Oxford: The Computers and Variant Texts Project.
- Spuler, David. 1992. *Comprehensive C*. New York: Prentice Hall.
- Youtie, Herbert C. 1966. 'Text and context in transcribing papyri'. *Greek*,

Roman, and Byzantine studies 7, 251-8.

Youtie, Herbert C. 1974. *The textual criticism of documentary papyri: prolegomena*. 2nd rev. and enlarged ed. Institute of Classical Studies bulletin supplement, 33. London: University of London.

CLASSICAL SCALING

Synopsis

Multivariate analysis

Multivariate analysis is defined and a number of its purposes are listed. One purpose is to show how a number of objects relate to each other, and scaling techniques are well suited to this end. A particular technique called classical scaling has been adopted for use in this study, where the objects are witnesses of Hebrews.

Classical scaling demonstration

J. Podani's *SYN-TAX* software is utilised for two demonstrations of the classical scaling technique. The first makes use of geographical data and the second is based on New Testament textual data taken from a well known study by Gordon D. Fee. The significance of resultant map axes is discussed. It appears that the axes of maps derived from this New Testament textual data can be interpreted geographically.

Data matrices

Data matrices are fundamental in multivariate analysis. Nomenclature, content, and construction of data matrices relevant to this study are addressed. My collation program generates data matrices from transcriptions of primary witnesses and quasi-transcriptions of supplementary witnesses. Nearly all of the quasi-transcriptions are generated from the sample data matrix, which records readings compiled from secondary sources.

Dissimilarity matrices

Dissimilarity matrices, which tabulate what might be understood as 'distances' between witnesses, are built from the data matrices. Their characteristics and means of construction are discussed.

Similarity coefficients

An essential aspect of dissimilarity matrix construction is the choice of a similarity coefficient. Many are available, but the nature of our data reduces the number that are appropriate. In the end, the range is narrowed to one, with the issue of 'double-zeros' playing an important

part in the final choice.

Multivariate analysis

Definition

Multivariate analysis is the statistical analysis of multivariate data that 'consist of observations on several different variables for a number of individuals or objects' (Chatfield and Collins, 1980, 3). In the present case, objects are witnesses to the text of Hebrews and variables are particular units such as words or punctuation that vary between the witnesses. Other areas of New Testament study can be illuminated by the use of multivariate analysis. For instance, David L. Mealand (1995, 61-92) has recently applied multivariate techniques in a stylistic analysis of the Pauline letters.

Multivariate analysis deals with a number of variables at once, whereas the more familiar univariate analysis only deals with one variable. To give an example, a survey might measure variables such as the heights, weights, voting habits, and incomes of a population of people. In univariate analysis, similarity between individuals could only be measured on the basis of one variable at a time. By contrast, multivariate analysis would allow the analysis of relationships among the population's individuals to take account of all four variables simultaneously. Multivariate analysis would also show whether relationships existed between the variables.

Purposes of multivariate analysis

Chatfield and Collins (1980, 6-8) list a number of reasons for applying multivariate analysis to a set of multivariate data:

Reduction of dimensionality

Every data set contains an underlying set of axes or dimensions that can be extracted by linear algebra. The data's variability is efficiently expressed in terms of these dimensions, which are uncorrelated and arranged in decreasing order of importance. It is often possible to account for a good deal of the variability by reference to only the first few most important dimensions. In this way, the dimensionality of the explanatory task is reduced to the number of dimensions that account for

a satisfactory proportion of the variability.

Data exploration

A large and complex data set is hard to comprehend in its raw form, but the many techniques available within multivariate analysis provide the researcher with a useful set of tools to characterise the data. Univariate analysis is typically used to test an existing hypothesis, whereas the results of multivariate analysis techniques tend to suggest new hypotheses.

Discovering relationships

Multivariate analytical tools can be used to discover relationships between variables on the one hand (variable-directed techniques), or objects on the other (individual-directed techniques). Variables can be compared by measuring their correlation. Objects are compared by calculating their mutual dissimilarities. Dissimilarity is generally analogous to distance and can be measured in a variety of ways. Similarity and dissimilarity are complementary, so a pair of objects with a weak dissimilarity have a strong similarity, and vice versa.

Classification

Cluster analysis is an individual-directed technique that divides objects into a set of groups. A technique named discriminant analysis is directed towards classifying an object into one of a set of previously defined groups.

Scaling

Another purpose of multivariate analysis is to show the relative dispositions of a set of objects. Classical scaling, also known as principal coordinate analysis, takes a matrix of object dissimilarities and finds a configuration of points that conforms to these inter-object 'distances'. Exact representation of the dissimilarities between a set of N objects requires $(N - 1)$ dimensions, but approximately correct dissimilarities can be represented in a smaller number of dimensions (Chatfield and Collins, 1980, 189). By this reduction of dimensionality, the object dissimilarities can be approximately represented with two-dimensional maps that plot points corresponding to the objects.

Ordinal scaling, also called non-metric multidimensional scaling, is concerned with the ranking of inter-object dissimilarities rather than their magnitudes. It is better to use this technique when it is not safe to assume that dissimilarities approximate Euclidean distances (Chatfield and Collins, 1980, 210). Ordinal scaling begins with a given initial configuration of points then uses an iterative procedure to search for a final configuration that is in good agreement with the rank order of dissimilarities. The initial configuration is either specified by the user or chosen at random. The final configuration depends upon the initial configuration, and there is no guarantee that a particular final configuration is the best possible (Chatfield and Collins, 1980, 207). Classical scaling does not suffer from this weakness because it finds a unique analytic solution which is always the best representation, provided that the dissimilarities are approximately Euclidean.

Any of these individual-directed techniques could be applied to find relationships between New Testament witnesses, while variable-directed techniques could be used to explore relationships among variant readings. As it turns out, both classical and ordinal scaling produce similar configurations of points when applied to data produced by the collation programs described in the last chapter. These configurations may be interpreted as maps of the textual history of Hebrews. Classical scaling has been adopted to produce the maps of this study because it provides a unique analytic solution and consumes less computer-time than ordinal scaling when given the same collation data to analyse.

Classical scaling demonstration

The following examples demonstrate the application of classical scaling to dissimilarity matrices of two different types. One type relates to actual distances while the other relates to percentage agreements between a sample of New Testament manuscript texts.

Actual distances

The inter-city distances, as the crow flies, for the capital cities of Australia's states and territories are given in the dissimilarity matrix of fig. 1. The information required to construct a map showing the relative positions of the cities is contained in this matrix, although it is hard to

visualise this inherent information using the matrix alone. One could start by getting an idea of which cities are closest to a particular city, then trying to perform the same process for every other city. This might result in a satisfactory mental picture for a few cities, but increasingly leads to confusion as more cities are considered.

Alternatively, the dissimilarity information can be processed with classical scaling software to produce the map shown in fig. 1. The multivariate analysis software used for this purpose is *SYN-TAX 5*, written by Dr János Podani (1995). The same software is used to construct all of the maps found in this thesis.

Apart from being reflected in the east-west direction, the map of fig. 2 represents the locations of Australia's capital cities quite well. The map is also rotated relative to conventional maps. Transformations such as reflection, inversion, and rotation are to be expected from a purely mathematical procedure which is not biased towards a particular frame of reference. The map also appears to be stretched in the east-west direction, but this is merely because the scales of the two axes are different.

The figures below the map are quantities generated during the analysis procedure. They give the percentage of variation in the dissimilarity matrix explained by each axis. In this case, the software informs us that the first two axes account for 49% and 22% of the dissimilarity information, respectively. That is, 29% of the variation is yet to be explained.

A third axis explains another 12% of the variation. Fig. 3 shows a plot of the first and third axes. The first axis is plotted again so that the two maps can be considered together. This allows a three-dimensional map to be visualised with the third axis standing perpendicular to a plane formed by the first two axes. Plotting the first and third dimensions results in quite a good mapping of the cities from Brisbane around to Adelaide, but inverts the relative positions of Perth and Darwin. Nevertheless, a total of 61% (i.e., 49% + 12%) of the dissimilarity information is reproduced by this map. The first map is a better representation of the physical reality and has a greater combined explanatory power. Altogether, the first three

dimensions explain 83% of the information contained in the dissimilarity matrix.

Data from Gordon D. Fee's study of John 1-9

Until now, researchers have examined tables of percentage agreements in order to explore relationships among texts. It has already been shown that the classical scaling procedure produces an effective representation of dissimilarity information in the form of maps. Given that a table of agreements can be readily transformed to a dissimilarity matrix, classical scaling can be expected to give an effective representation of the relative dispositions of a set of New Testament witnesses. To demonstrate that this is so, three tables of percentage agreements from a study by Gordon D. Fee (1968, 23-44) will be subjected to the procedure.

Tables 1 to 3 of Fee's article (1968, 30, 35) give percentage agreements between a number of witnesses to the text of John's Gospel for variation units in chapter 4, chapters 1-8, and chapter 9, respectively. Dissimilarity matrix entries are calculated from these figures by subtracting each percentage agreement from 100 to produce percentage disagreements. Information concerning correctors of P66 and U1 is excluded as the percentage agreements with their corresponding originals are not given. The resultant dissimilarity matrices are shown in figs. 4 to 6.

As noted by Fee, Codex Sinaiticus (U1) changes its allegiances at chapter 9. The shift can be discerned from the tables, but is much easier to see in the corresponding classical scaling maps, figs. 7 to 9. Besides the shift, the relative positions of all the other witnesses become apparent. A few pictures present what was once described in a thousand words.

The position of Codex Sinaiticus relative to witnesses such as P75 and Codex Vaticanus (U3) clearly changes when fig. 9 is compared with figs. 7 and 8. The maps are also true to what is already known about other texts. P75 and U3 are known to be closely related, and their mapped positions are close together. As expected, Codex Alexandrinus (U2) and the *Textus Receptus* are near neighbours as well. The fact that this technique produces results that are consistent with current knowledge encourages us to trust the maps as guides to previously unexplored

realms.

At this point new insights present themselves. P66 undergoes a change in relative position between the first two maps. This suggests that it, too, is subject to block mixture in these chapters of John. Fig. 9 is analogous to figs. 7 and 8, except that a rotation and reflection have taken place. (In addition, Codex Ephraemi Rescriptus (U4) is missing from fig. 9.) Once the requisite mental gymnastics are performed to make fig. 9 comparable with figs. 7 and 8, it becomes apparent that the position of P66 in fig. 7 is anomalous. In figs. 8 and 9, P66 does not lie too far from a line drawn between Codex Bezae (U5) and the Washington codex of the Gospels (U32). In fig. 7, however, it lies between the positions of U32 and P75-U3. To use more conventional terminology, the text of P66 in John 1 to 9 appears to be a mixture of Western and Alexandrian texts. In John 4 it appears to lose some of its Western characteristics.

Significance of the axes

Further insight into these maps can be gained by investigating the significance of their axes. Classical scaling map axes are mathematical constructs that correspond to principal factors underlying variation in the analysed data set. Axis 1 aligns with the most significant factor, axis two with the second most significant, and so on. Even though it is not always possible to find a clear interpretation, the meaning of an axis can be explored by examining its correlation with candidate measures. Each measure is shown to be significant or not, depending on how strongly it correlates with the most important axes. If a measure has a low correlation, then the phenomenon it measures is not an important cause of variation in the data.

The axes of the geographical data maps happen to correlate quite well with conventional longitude and latitude axes, once rotated through about 30 degrees. This is to be expected because the dissimilarity matrix consists purely of geographical information. Critical principles that have been brought to bear upon the New Testament suggest a set of candidate measures to compare with map axes derived from New Testament textual data. Measures might be constructed according to the ability of one reading to explain the origin of another, how authentic a reading sounds, orthodoxy, and so on.

Taking a different tack, the theory of local texts advocated by B. H. Streeter in *The four Gospels* (1925) suggests that geography and time might be important factors. Perhaps 'distances' between texts reflect Euclidean distances between the places in which the corresponding manuscripts were copied. The textual standardisation which seems to have taken place over time might also be apparent when the positions of various manuscripts are considered in relation to the dates of their texts. There are precedents for such an approach, with Chatfield and Collins (1980, 208) referring to cases where archaeological research and scaling techniques have combined to construct maps that correspond to their geographical analogues.

Returning to the example, it is reasonable to think that P66, P75, and U32 began their lives in the dry climes of Egypt, given that they were buried there. (Place of recovery is not proof of provenance, as the great uncials show. But they are exceptional manuscripts, and their value would have motivated the ancients to transport them for safe keeping.) Given that P66, P75, and U32 are Egyptian, we can expect them to congregate together in an area that corresponds to Egypt, if the maps reflect geographical influences.

Concerning the other witnesses, Milne and Skeat (1938, 69) are inclined towards the view that U1 originated in Caesarea, although others favour Egypt (e.g., Ropes, 1926, xlvii-xlviii). As far as the text of U5 is concerned, no one knows where the so-called Western text originated, although there is speculation that it came from the East Ñ perhaps Antioch (Petersen, 1994, 142; Ropes, 1926, ccxlv). The *Textus Receptus* and the text of U2 in the Gospels are commonly associated with Constantinople.

Strangely enough, the maps are entirely consistent with this geographical distribution, as can be seen by rotating the map of John 9 so that U2-TR faces away from the reader. The U2-TR text now lies in the 'northerly' Constantinopolitan region, the P75-U3 text lies in the 'southerly' Egyptian region, and the U5 text lies in the 'easterly' Syrian region. The other maps bear the same interpretation, except that they are reflected in the east-west direction, and are relatively compressed in the north-south

direction. Once an east-west reflection is performed, U1 lies in the 'south-easterly' Caesarean region, in these two maps at least. Could it be that these dissimilarity matrices contain geographical information? If so, then classical scaling maps can be used to locate the place of origin of witness texts, provided they are not mixed texts.

In attempting to draw geographical implications from a classical scaling map, it should be remembered that the north-south and east-west directions need not be perpendicular, of the same scale, or aligned with the map axes. Also, as far as textual variation is concerned, implications regarding a text's place of origin do not necessarily extend to the manuscript that bears the text. Eldon J. Epp (1995, 9) has pointed out that manuscripts could be rapidly transported from one part of the Roman Empire to another. As a consequence of this textual mobility, manuscripts could be copied from exotic exemplars. It is possible that spelling variation provides a more reliable guide to a manuscript's place of origin than does textual variation; even if a manuscript had an exotic exemplar, its scribe would still have tended to spell according to local custom.

Besides geographical information, the dissimilarity matrices might also contain temporal information which is revealed as an arrow of time in the maps. The correlation between witness dates and axis coordinates can be calculated to test whether this is so. To illustrate, a test for correlation between the axes of the John 1-8 map and witness dates is performed here. Witness coordinates are obtained from the software output, while estimated dates are derived from those given in NA27, appendix 1. Any century-style date is converted to an approximate year by taking the mid-point of the given range.

Map coordinates vs. estimated date

	<i>P66</i>	<i>P75</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>	<i>U4</i>	<i>U5</i>	<i>U32</i>
<i>Axis 1</i>	0.440	-2.775	4.714	-1.057	-2.687	-1.726	4.805	-0.992
<i>Axis 2</i>	0.937	1.699	2.045	-3.498	1.902	0.878	-0.944	0.215
<i>Date</i>	200	250	350	450	350	450	450	450

The strength of linear association between axis 1 coordinates and the

estimated dates is given by the correlation coefficient, r , which is 0.132 here. This means that $r^2 \sim 2\%$ of the variance in the estimated dates is explained by least-squares linear regression on the first axis coordinate (Moore and McCabe, 1993, 176). In other words, the first axis coordinate is a poor indicator of manuscript date. The correlation coefficient for the second axis is even smaller at 0.022, meaning that this axis has little or no relationship to estimated manuscript date as well. This is not to say that the axes do not have temporal significance. It is possible that there is a correlation with the date of a text, however that might be estimated, but that the date of a manuscript does not correlate well with the date of the text it reproduces.

One last remark should be made concerning temporal interpretation of these maps. According to the first two maps, witnesses which might be associated with Egypt, namely P66, P75, U3, U4, and U32, seem to form a more primitive group than the 'eastern' U1 and U5, and 'northern' U2 and *Textus Receptus*. This is not a safe conclusion. If the two papyri are excluded from consideration, the groups do not display significantly different average dates. The papyri have survived because they are Egyptian, and it is reasonable to argue that older manuscripts would have survived from other parts of the Mediterranean rim, but for climatic circumstances. What is required to date these textual clusters is a set of witnesses with datable texts.

This brings the demonstration of classical scaling to a close. As the procedure is a scaling technique, the units of measurement employed for dissimilarity matrices do not affect the results. Given the same relative separation between objects, the same maps will be produced regardless of whether dissimilarities are measured in kilometres, percentages, or any other units. The technique is valid provided that the dissimilarities are approximately Euclidean; that is, they should behave in a manner similar to conventional distances. The question of whether or not dissimilarities derived from agreements between New Testament witnesses are Euclidean will be addressed in a later chapter.

Data matrices

Dissimilarity matrices are derived from data matrices that contain the

raw data upon which multivariate analysis is to be performed. Data matrices are fundamental to multivariate analysis and, therefore, to the production of classical scaling maps. This section discusses data matrices in general and has a particular emphasis on their application to New Testament textual data.

Notation

Data for P variables and N objects can be represented as a $P \times N$ data matrix. It is conventional in linear algebra to give the number of rows of a matrix first and the number of columns second. Chatfield and Collins (1980, 6) prefer to construct their data matrices with objects heading rows and variables heading columns: that is, they use $N \times P$ matrices. In Podani's software, however, variables head rows and objects head columns. This is the system used here. The difference is only a matter of convention and has no effect on subsequent analysis.

Data types

Data matrix values may be classified into a number of types. Continuous data can take on any value, whereas discrete data can only take on distinct values. Heights are continuous, whereas answers to a multiple choice questionnaire are discrete. The data encountered in relation to New Testament witness collations are discrete as they signify distinct readings.

Discrete states of this kind are called nominal because they are represented by labels that have no quantitative significance. For instance, a particular reading of a variation unit may be labelled as 'zero', another as 'one', and so on. The corresponding data matrix will be filled with numbers, but these function only as labels so it does not make sense to perform operations such as multiplication or addition upon them. The only meaningful action which can be performed is comparison. If two objects have the same label for the same variable then they have the same reading there, otherwise they are different.

Nominal data may be ordinal. That is, they may be arranged in order. It is conceivable that readings could be arranged in an order of originality if there were a clear direction of development from one to another to another, and so on. This possibility is noted here, but for the present

study New Testament data matrix values will be assumed to be nominal data without ordinal significance.

A set of variation unit readings can be given a binary or multistate representation. A multistate representation is achieved simply by assigning a unique label to each reading, whereas a binary or two state representation requires that the variation unit be divided up into components so that each possible state can be indicated by noting presence or absence of individual components. According to A. D. Gordon, multistate data with some number of states can always be expressed as the same number of binary components (Podani, 1994, 14). To illustrate, three readings are given for the variation unit at Hebrews 1.3 in UBS4. The corresponding row of a multistate data matrix would appear as follows:

	<i>P46</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>	<i>U6</i>	<i>É</i>
<i>1.3</i>	2	0	0	0	1	<i>É</i>

Here, 'zero' is used to signify the first reading, 'one' the second, 'two' the third, and so on. A binary representation would look like this:

	<i>P46</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>	<i>U6</i>	<i>É</i>
<i>1.3a</i>	0	1	1	1	0	<i>É</i>
<i>1.3b</i>	0	0	0	0	1	<i>É</i>
<i>1.3c</i>	1	0	0	0	0	<i>É</i>

Now, 'zero' represents absence of the corresponding variable and 'one' represents presence. The coding may be reversed so that 'zero' means presence and 'one' absence without affecting subsequent analysis, provided that the data is nominal (Podani, 1994, 15). The former convention has been adopted here because it is more intuitive to code absence by 'zero' and presence by 'one'.

The synthetic text collation procedure described in the last chapter was developed in order to allow New Testament textual variation to be presented as binary data matrices. Binary rather than multistate data matrices are preferable because they admit of a wider range of the similarity coefficients used to construct dissimilarity matrices.

Missing data

It is important to have a matrix entry for missing data because many witnesses are fragmentary. I use 'negative one' (-1) for this purpose as the *SYN-TAX* software interprets a negative value as a missing datum and, therefore, ignores it. Any unit with a certainty that is below the threshold level specified in my collation programs is interpreted as a missing datum.

Missing data have the potential to produce undesirable effects when it comes to constructing dissimilarity matrices. These can be avoided by discarding data matrix rows that contain missing data, at the cost of losing the information they contain about witnesses that are extant in those places.

Variables not affecting relationships

Two classes of variables do not contribute to analysis which aims to discover relationships between witnesses. The first is a singleton variable in which one witness has a particular state and all other witnesses have another. The second class displays no variation across the witnesses. Rows corresponding to these two kinds of variable can be discarded without affecting subsequent classical scaling analysis.

In binary matrices, a singleton variation appears as a single 'zero' among a row of 'ones', or vice versa. A row corresponding to a variable with no variation is entirely populated either by 'ones' or by 'zeros'. Missing data are ignored when determining whether a variable displays singleton variation or no variation.

The principal data matrices of this study

The collation software described in the last chapter generates data matrices that represent the texts contained in the input transcriptions. I call these 'principal data matrices' in order to distinguish them from the sample data matrix discussed below. Principal data matrices are the basis of subsequent analysis to produce classical scaling maps. Each one is arranged as follows:

$$w(1) \quad w(2) \quad w(3) \quad \dot{E} \quad w(p)$$

$u(1)$	$e(1,1)$	$e(1,2)$	$e(1,3)$	$\dot{E}$	$e(1,p)$
$u(2)$	$e(2,1)$	$e(2,2)$	$e(2,3)$	$\dot{E}$	$e(2,p)$
$u(3)$	$e(3,1)$	$e(3,2)$	$e(3,3)$	$\dot{E}$	$e(3,p)$
$\dot{E}$	$\dot{E}$	$\dot{E}$	$\dot{E}$	$\dot{E}$	$\dot{E}$
$u(n)$	$e(n,1)$	$e(n,2)$	$e(n,3)$	$\dot{E}$	$e(n,p)$

The rows relate to individual units, with each unit being a word, punctuation mark, or format marker of the synthetic text. Columns relate to witnesses, and numerical entries indicate presence or absence of units for a particular witness. (Alternatively, the entries indicate presence or absence of witnesses for a particular unit.) To use matrix nomenclature, units head N rows of variables, and witnesses head P columns of objects, giving an $N \times P$ matrix of discrete, nominal, binary data. Presence is signified by 'one' (1), absence by 'zero' (0), while 'negative one' (-1) signifies a missing datum.

The sample data matrix

The witnesses used to generate the principal data matrices consist of primary and supplementary texts. Primary texts are derived directly from the accessible papyrus and uncial manuscripts themselves. Supplementary texts are constructed from secondary sources such as critical editions. They have been incorporated to provide additional reference points for the classical scaling maps of Hebrews.

Four of the supplementary texts are manually constructed. Two are texts of Church Fathers covered by *The New Testament in the Greek Fathers* series. Gregory of Nyssa's text is taken from the volume written by James A. Brooks (1991), while Cyril of Jerusalem's text is taken from the volume by Roderic L. Mullen (1997). The other manually constructed texts are of U278 and U285. These are two of the manuscripts found at Saint Catherine's monastery in 1975. Access to these manuscripts is restricted, and I have not been able to obtain photographs from which to make transcriptions. Whereas they have not yet been published, their texts can be reconstructed from the apparatus of Wachtel and Witte's *Das Neue Testament auf Papyrus 2/2* (1994). The resultant constructs do not reflect the spelling of the manuscripts because the spellings in the apparatus are generally levelled. A third manuscript from the 1975 Saint

Catherine's find, U280, also contains part of Hebrews. Its text is too fragmentary to be included by reference to anything but a complete transcription.

The rest of the supplementary witnesses are constructed from the sample data matrix. This matrix specifies the readings of its constituent witnesses at a number of sample variation units. The variation units are those of the UBS4 apparatus of Hebrews, excluding one that relates to accents alone (Heb 5.12). This leaves 43 variation units that provide a sample of the 99 witness texts surveyed in this manner.

In constructing the sample data matrix, consecutive readings of a particular variation unit were assigned consecutive numbers beginning with 'zero' for the reading of the UBS4 text then progressing through the positive integers until each reading had been assigned a number. The readings and assigned numbers of each variation unit are listed in the appendix entitled *Basis for criteria data*. They conform to the UBS4 apparatus except in a few places (Heb 2.8, 3.6b, and 10.1a) where I adopted a different scheme to represent the variation.

The sample data matrix specifies the readings found in a variety of evidence including minuscules, versions, Church Fathers, modern authors, and editions. It also gives readings selected according to a number of critical principles. The matrix consists of multistate data because the UBS4 apparatus can give more than two readings for a variation unit. When a witness is not cited, 'negative one' is entered to signify a missing datum.

As far as the minuscules and versions are concerned, the sample data matrix is based on information found in the UBS4 apparatus. Distinctions that the apparatus marks with parentheses and qualifying superscripts such as 'vid' or 'dub' are ignored. A siglum followed by an asterisk to signify a pre-correction reading is treated as referring to the first hand of the witness in question.

Where witnesses of a generic class divide between readings, the class is assigned the majority reading. If the witnesses are evenly divided, the generic class is treated as if missing for that variation unit. In the case of

patristic citations, commentary readings take precedence over lemma readings because they are less likely to have been altered towards a more popular text during transmission:

<i>Alternatives</i>	<i>Assigned reading</i>
vg; vg mss	vg
vg ms; vg mss	vg mss
slav ms; slav ms	Missing
Cyril 1/3; Cyril 2/3	Cyril 2/3
Theodoret lem; Theodoret com	Theodoret com

The following general comments relate to individual classes of witnesses included in the sample data matrix. Further notes concerning specific supplementary witnesses are given in the appendix entitled *Supplementary texts*.

Minuscules

In order to reduce clutter in the classical scaling maps, minuscules have only been included if they are classified as category I or II by the Alands (1989, 129f.), or if they are marked by an asterisk in the fourth column of NA27, appendix 1.

Versions

Non-Greek translations are not always able to represent features found in the Greek. For example, the definite article has no Latin equivalent. This raises the possibility of a version supporting more than one reading of a variation unit in the UBS4 apparatus. A case in point is Heb 11.11, where the apparatus places certain Latin witnesses in parentheses because they may support more than one of the alternative readings. When this occurs, the relevant witnesses are treated as if missing.

Church Fathers

The UBS4 editors are quite rigorous in their approach to patristic citations. As a result, only a few of the Church Fathers are reported with sufficient frequency to allow their inclusion in the multivariate analysis process. This is unfortunate because the Fathers provide important reference points by which to interpret the results of the analysis. In order to include more Church Fathers in subsequent analysis, I have

supplemented the patristic citations of the UBS4 apparatus with citations gleaned from reference editions including Tischendorf's eighth edition (1872), Souter's *Novum Testamentum Graece* (1947), Zuntz's *Text of the epistles* (1953), and UBS3, which was not as strict in its approach to this class of evidence as UBS4. In short, admission standards have been lowered to include more patristic references. Consequently, patristic reference points in the classical scaling maps should be regarded with a degree of caution.

I have generally included citations that are marked as subject to doubt. When conflicting citations occurred, the most recent reference edition was generally followed and a note of the conflict made in the supplementary text notes. Various courses of action are taken when a Father's citations encompass alternative readings of a variation unit. If one reading is cited more frequently than the others, it is adopted. If the choice is between a Greek and non-Greek citation, the Greek one is chosen. Where commentaries are concerned, the lemma text is entered if one reading is supported in the lemma and another in the associated commentary. No text has been constructed for variation units in which evidence is evenly distributed between alternative readings. Citations attributed to Primasius have been counted as citations by Cassiodorus; the school of Cassiodorus is now thought to have been responsible for the works on the Pauline epistles that were formerly attributed to Primasius (Souter, 1954, 83).

Fig. 10 lists Church Fathers incorporated as supplementary witnesses. Approximate terminal dates and name abbreviations are given as well, with many of the abbreviations adapted from Tischendorf. The expanded names and dates are taken from the UBS4 introduction and the Alands' *Text of the New Testament* (1989).

Authors and editions

The preferred texts of a number of modern authors are taken from their commentaries on Hebrews. Readings of modern editions are taken from the editions themselves or from appendix 3 of NA27.

Critical principles

The commentaries also provide examples of modern authors employing

critical thought to distinguish between primary and secondary readings. They employ principles that are founded on a knowledge of the transmission phenomena and scribal tendencies that acted to corrupt the text in the first place. Readings selected in this manner are recorded under twelve critical principles columns of the sample data matrix.

The history of New Testament textual criticism stretches back to the first centuries of the text's transmission. Origen was one early textual critic who left us records of variants he knew to exist. His critical methods may have tended to drive the text away from its primitive state. Gordon D. Fee (1993, 257) quotes from the conclusion to Frank Pack's 1948 dissertation entitled *The methodology of Origen as a textual critic in arriving at the text of the New Testament*:

[Origen's] handling of the text closely parallels the work done by later editors and textual workers in shaping the stylized Byzantine text. The process that ended with the Byzantine text-type finds its beginnings in Origen's methodology, for it was a process of 'correction' of the knowledge, use and conflation of different textual traditions, and the handling of the text with the interests of teaching and preaching in mind.

A renewed quest for the original Greek text has emerged since the time of Erasmus. Eldon J. Epp (1993a, 141-173) traces the development of critical principles designed to identify primitive readings and isolate corruptions. The following principles are derived from his survey. They are divided along the conventional lines of internal and external criteria.

Each criterion is framed as a statement of preference that positively identifies the primitive reading (see Epp, 1993a, 163). In some cases, a corollary that serves to indicate the secondary nature of other readings is appended. A short title that serves as a column label in the sample data matrix is also provided. In many cases, a criterion or corollary is followed by a name and approximate date from Epp's identification of the first person to enunciate the principle in a published work.

Internal criteria

Appropriate (Origen ~230 CE)

'Prefer the reading that is appropriate to the context.'

The first impulse in dealing with a variation is usually to lean on Intrinsic Probability, that is, to consider which of two readings makes the best sense, and to decide between them accordingly. The decision may be made either by an immediate and as it were intuitive judgement, or by weighing cautiously various elements which go to make up what is called sense, such as conformity to grammar and congruity to the purport of the rest of the sentence and of the larger context (Westcott and Hort, 1881b, 20).

Authentic (Wettstein ~1730)

'Prefer the reading that is characteristic of the author.'

Westcott and Hort (1881b, 20) describe such a reading as one with 'congruity to the usual style of the author and to his matter in other passages.' For present purposes, style includes thought, theology, and ideology that are typical of the author (see Epp, 1993a, 163). Another statement of this principle is, 'Prefer the reading most likely to have been written by the author.'

Difficult (Mill ~1707)

'Prefer the more difficult reading.'

The logical foundation of this criterion is the concept of transcriptional probability; corruptions towards what a scribe would hear, see, or think to be right, easy, or best are more likely than those in the opposite direction.

A reading which does not allure by too great facility, but shines by its native dignity, is always to be preferred to that which may fairly be supposed to owe its origin to either the carelessness or the injudicious care of copyists (Bengel, quoted by Epp, 1993a, 146).

Preferable to others is the reading that conveys É an apparently false meaning, but which meaning, upon thorough examination, is found to be true (Griesbach, quoted by Epp, 1993a, 152).

The more difficult is sometimes the harsher reading. Kilpatrick would

have included readings that were linguistic and political anachronisms at the time of copying.

Corollary

'Smooth and easy readings are not necessarily genuine.'

As Westcott and Hort (1881b, 27) wrote, 'readings originating with scribes must always at the time have combined the appearance of improvement with the absence of its reality.'

Discordant (Von Mastricht ~1711)

'Prefer the reading that is not in harmony with a parallel passage.'

In the case of the epistle to the Hebrews, parallels are usually from the Septuagint or elsewhere in the epistle, but are only rarely from other parts of the New Testament. Griesbach recognised that parallels may also be found in lectionaries, scholia, and commentaries. Liturgical phrases comprise yet another source.

Elemental

'Prefer the reading that is not a conflation of alternative elemental readings.'

This principle is inherent in Tischendorf's statement given below in relation to the 'explanatory' criterion.

Where we find a variation with three variants, two of them simple alternatives to each other, and the third a combination of the other two, there is usually a strong presumption that the third is the latest and due to mixture, not the third the earliest and the other two due to two independent impulses of simplification (Westcott and Hort, 1881b, 49).

Explanatory (Griesbach ~1796)

'Prefer the reading that explains the origin of the others.'

This was Tischendorf's cardinal rule:

More probable than others is the reading that appears to have occasioned

the other readings or that still contains within itself elements of the other readings (Tischendorf, paraphrased by Epp, 1993a, 155-6).

Corollary (Bengel ~1725)

'Which reading is likely to have arisen from the others?'

Native (Griesbach ~1796)

'Prefer the reading that does not appear to have been introduced from a version.'

Secular (Griesbach ~1796)

'Prefer the reading that does not seem to have arisen from pious or monastic motivations.'

Short (Wettstein ~1730)

'Prefer the shorter reading.'

A carefully qualified form of this principle was Griesbach's cardinal rule.

Corollary

'The reading that appears to be interpolated is less likely to be original.'

Stable

'Prefer the stable reading.'

That is, reject readings that are absent from some witnesses and have a variable position in the rest. This criterion may not be valid for longer passages (see Ross, 1992, 156).

Unorthodox (Wettstein ~1730)

'Prefer the unorthodox reading.'

Interest in this criterion has recently been revived by Bart D. Ehrman's book, *The Orthodox corruption of scripture* (1993).

External criteria

Diverse

'Prefer the reading supported by diverse witnesses.'

This criterion refers to support by distinct classes of independent evidence, although it is often applied in the more restricted sense of geographical dispersion. According to Epp (1993a, 145), Mill appears to have utilised this principle in compiling his edition of 1707. Epp (1993a, 147) also quotes a statement by Bengel that has a similar thrust: 'witnesses which *differ* in country, age, and language, [are to be preferred] to those which are closely connected with each other'.

Early (Jerome ~380)

'Prefer the reading supported by earlier witnesses.'

Later writers recognised the need to consider patristic and versional evidence as well:

[S]ince the original autographs (which were in Greek) can alone claim to be the Fountain-head, the highest value belongs to those streams which are least removed from it; that is, to the most ancient codices, in Greek, Latin, &c. (Bengel, quoted by Epp, 1993a, 147).

This rule also applies to later manuscripts that demonstrably preserve earlier texts, such as M33 and M1739.

Eugenic (Westcott and Hort ~1881)

'Prefer the reading supported by a reliable group of witnesses.'

Reliability of groups is determined by scrutinising their common readings through internal criticism:

If we find, for instance, in any group of documents a succession of readings exhibiting an exceptional purity of text, that is, readings which the fullest consideration of Internal Evidence pronounces to be right in opposition to formidable arrays of Documentary Evidence, the cause must be that, as far at least as these readings are concerned, some one exceptionally pure MS was the common ancestor of all the members of the group; and that accordingly a recurrence of this consent marks a recurrence of joint derivation from that particular origin, and accordingly a

strong presumption that exceptional purity is to be looked for here again (Westcott and Hort, 1881b, 60-61).

Manifold (Bengel ~1725)

'Prefer the reading supported by the agreement of ancient groups of witnesses.'

Bengel's classification of known sources of the NT text É enunciated for the first time in a systematic formulation the significant and fundamental principle that *textual witnesses must be weighed and not merely counted* (Epp, 1993a, 148).

Bengel divided manuscripts into African and Asiatic families. Griesbach divided them into the Western, Alexandrian, and the more recent Byzantine recensions. He thought that a reading supported by all three or the two more ancient ones was likely to be original. If one of the ancient recensions had a reading that differed from the others, Griesbach evaluated it in the light of characteristic faults of the recensions and by internal criteria (Epp, 1993a, 147, 152-3).

Grouping indicates lines of common ancestry that, taken together, comprise a portrait of the text's history. Westcott and Hort (1881b, 40) wrote:

The more exactly we are able to trace the chief ramifications of the [genealogical] tree, and to determine the places of the several documents among the branches, the more secure will be the foundations laid for a criticism capable of distinguishing the original text from its successive corruptions.

One of their most famous precepts follows immediately (40):

ALL TRUSTWORTHY RESTORATION OF CORRUPTED TEXTS IS
FOUNDED ON THE STUDY OF THEIR HISTORY.

Prevalent (Origen ~220)

'Prefer the reading found in the majority of manuscripts.'

This criterion runs counter to the principle that witnesses should be weighed and not counted.

Reliable

'Prefer the reading supported by reliable witnesses.'

Jerome's preference for carefully written manuscripts is an early expression of this principle. Reliability of a witness is evaluated through examination of its readings in the light of internal evidence, and this is the logical context in which Westcott and Hort formulated another one of their famous precepts (1881b, 31):

KNOWLEDGE OF DOCUMENTS SHOULD PRECEDE FINAL
JUDGEMENT UPON READINGS.

They expand upon this statement as follows (1881b, 32):

Where then one of the documents is found habitually to contain these morally certain or at least strongly preferred readings, and the other habitually to contain their rejected rivals, we can have no doubt, first, that the text of the first has been transmitted in comparative purity, and that the text of the second has suffered comparatively large corruption; and next, that the superiority of the first must be as great in the variations in which Internal Evidence of Readings has furnished no decisive criterion as in those which have enabled us to form a comparative appreciation of the two texts.

Selection of criteria

Many of these criteria are suspect. Preference for the majority reading (i.e., the prevalent criterion) is not widely favoured because it neglects to consider the possibility that events in the text's transmission may have conspired to relegate the original reading to a minority of witnesses:

[The assumption that numerical superiority ought to carry considerable weight] is completely negated by the facts adduced [before], which shew that, since the same numerical relations among existing documents are compatible with the utmost dissimilarity in the numerical relations among

their ancestors, no available presumptions whatever as to text can be obtained from number alone, that is, from number not as yet interpreted by descent (Westcott and Hort, 1881b, 44).

There is evidence to show that preference for the shorter reading is not a reliable principle as it stands (cf. Royse, 1981; Head, 1990). Proper use requires limitation, as exemplified by Griesbach (see Epp, 1993a, 151). One situation where preference for the shorter reading is not appropriate is where it is likely that an omission has occurred through *homoioteleuton*.

This is not the only criterion that would gain from qualification. Tests that search for the more difficult reading could be broken down into a number of specific grammatical categories such as omission of a pronoun, omission of an article, unusual word order, and so on (see Fee, 1993, 268-9). All of the criteria stand to benefit from a better understanding of the corruptive tendencies which they are designed to counter.

Independence is desirable in textual criteria. If two criteria are dependent then their contribution to deciding the originality of a reading is reduced relative to two independent criteria. This is analogous to a situation where dependent manuscripts are given less weight than independent ones. In the context of a data matrix, criteria that merely repeat what is already implied by other information are superfluous. To give an example, nothing is gained by using the external criteria to record scholarly opinions of which reading is supported by a certain group of manuscripts when this is already known from the documentary witness columns of the sample data matrix.

For the sake of completeness, and to allow comparison, suspect or dependent criteria have generally been retained rather than rejected. The 'appropriate' and 'authentic' criteria are combined under the latter heading because the distinction between a reading that is appropriate to the context and one that is characteristic of the author is often vague. A number of criteria that are infrequently employed have been subsumed into closely related but broader criteria. Accordingly, 'native' readings are listed under the 'discordant' criterion because they do not conform to the

versional parallel. Similarly, 'secular' and 'unorthodox' readings appear under the 'difficult' criterion as they might have troubled a typical scribe. The 'reliable' criterion is used for readings that would otherwise have been classified as 'eugenic'. This is because the hypothetical common ancestor of a reliable group of witnesses would itself constitute a reliable witness.

This leaves the following twelve criteria for use in the sample data matrix: 'authentic', 'difficult', 'discordant', 'elemental', 'explanatory', 'short', 'stable', 'diverse', 'early', 'manifold', 'prevalent', and 'reliable'.

Basis for criteria data

The appendix entitled *Basis for criteria data* classifies scholarly arguments for and against particular readings according to these critical principles. A summary of associated textual decisions is in the next appendix, *Tabular summary of criteria data*. Wherever a criterion gives a clear vote in favour of a particular reading, a corresponding entry has been recorded in the sample data matrix.

As a result of the polemic nature of the classification process, various conflicts of opinion arise that must be resolved before corresponding entries can be made in the data matrix. Such a case is illustrated by reference to Heb 1.3 in the *Basis for criteria data*. Ellingworth's statement is taken as support for reading '0' (aujtu) according to the 'short', 'reliable', and 'authentic' criteria, while Zuntz's statement is taken as opposition according to the 'authentic' and 'explanatory' criteria. Furthermore, statements by Zuntz, again, are taken to support reading '1' (diÆ eJautou) according to the 'elemental', 'authentic', and 'explanatory' criteria, while Attridge's opposition to the same reading has been classified according to the 'authentic', 'explanatory', and 'manifold' criteria.

This leads to conflicts over which readings are supported by the 'authentic' and 'explanatory' criteria. When such clashes occur, an attempt is made to weigh the merits of the opposing arguments. If none prevail then no entry is made under the relevant criterion for the variation unit in question. That is, the criterion is left indeterminate and is not marked

with a number corresponding to a reading. If the argument for one of the readings is compelling then an entry is made under the corresponding criterion. Decisions made in resolving opposed views are explained in the appended notes.

No readings are classified without scholarly concurrence even though it is tempting to do so when a reading fits squarely into one of the criteria but none of the scholars mentions the fact. I have taken this approach to ensure that the sample data is always founded on recognised authoritative sources.

The use of a negative 'against' category accommodates scholarly opinions which oppose readings, but can sometimes result in classifications which seem strange at first sight. For instance, a scholar may say that a reading has a parallel in another place. This comment would be classified as a vote against that reading according to the 'discordant' criterion; as the criterion favours readings without parallels, it must be against one with a parallel.

If a criterion opposes a reading, it may or may not support an opposing reading. If there are only two alternatives, or if it is clear that a scholar's opposition to one reading implies support for only one other, then there is no ambiguity. In such cases, a vote by the criterion against one reading is taken as support for the other. Otherwise, the opposition cannot be recorded in the sample data matrix because it is only permissible to select one reading from a variation unit for inclusion in the criteria columns. A similar situation applies when a scholar narrows the field of favoured readings, but does not finally settle on one. This inability to cope with non-specific judgments is a result of the use of multi-state variables in the sample data matrix. Data matrices constructed from binary variables never suffer from this problem because a vote against one state necessarily implies support for the other.

A subjective element enters into the categorisation process when scholarly support is more implicit than explicit. When this occurs, I have attempted to choose the most appropriate and specific categories to convey the scholar's intent. To illustrate, Metzger (1994, 593) writes that the inclusion of wJ" iJmavtion at Heb 1.12b is 'strongly supported by

, 46 A B (D*) 1739 (it^d) arm eth'. I have interpreted this 'strong' support as 'reliable' (because of the well respected Greek witnesses in the list) and 'diverse' (because of the versional support).

Scholarly statements are the reservoir from which critical support for particular readings has been drawn. A statement may constitute critical support for one reading even though the scholar concludes by choosing another reading. For example, Zuntz (1953, 172) writes 'the psalm verse kai; katevsthsa"É is in almost all ancient (and in very many recent) manuscripts and in practically all versions'. This is taken as support for the psalm verse according to the 'early', 'prevalent', and 'diverse' criteria, despite the fact that Zuntz regards it as secondary.

Echoes of earlier commentators are often heard in later commentaries. In addition, obvious facts tend to be stated repeatedly, either through reference to another author or independently. As nothing is gained by repetition, an opinion of this kind is quoted only once, usually by reference to its earliest occurrence.

Construction of quasi-transcriptions

The collation software that generates the principal data matrices requires witness texts to be presented as transcriptions. As a consequence, quasi-transcriptions of the supplementary texts must be constructed from the secondary source data. This is achieved by replacing the readings of the UBS4 text with the readings specified in the secondary sources.

The supplementary witnesses are tagged as reconstructed text everywhere except for the places where their readings are explicitly given. In other words, their texts are only treated as established when specifically cited in the secondary sources. If this strategy were not employed, each constructed witness would appear more similar to the UBS4 base text than it really is. This is because each would always agree with the UBS4 text in variation units that are not listed in the UBS4 apparatus.

In contrast to this general strategy, I have assumed that the extant text of U278 conforms to the base text except as reported otherwise by Wachtel and Witte (1994). The reason for doing so is that Wachtel and Witte give

a comprehensive account of its variations from the base text. Also, appendix 1 of NA27 shows that U278 has no lacunae in Hebrews up until the point where it fails.

A utility program named *CT* for 'Construct Texts' is used to generate quasi-transcriptions of supplementary texts from the sample data matrix, a variation units key, and the UBS4 text. Part of the sample data matrix, which actually contains 43 variation units and 103 witnesses, is printed here for illustration:

<i>ref.</i>	<i>M33</i>	<i>M81</i>	<i>M104</i>	<i>M256</i>	<i>M365</i>	<i>M1175</i>	<i>M1739</i>	<i>M1881</i>	<i>M1962</i>	<i>M2127</i>
<i>1.3</i>	0	0	2	2	2	0	1	1	0	2
<i>1.8</i>	0	0	0	0	0	0	0	0	0	0
<i>1.12a</i>	0	0	0	0	0	0	0	0	0	0
<i>1.12b</i>	1	1	1	1	1	1	0	1	1	1
<i>2.7</i>	1	1	1	1	1	0	1	1	1	1
<i>2.8</i>	0	0	0	0	0	0	0	0	0	0
<i>2.9</i>	0	0	0	0	0	0	1	0	0	0
<i>3.2</i>	0	0	0	0	0	0	0	0	0	0
<i>3.6a</i>	0	0	0	0	0	0	2	0	0	0
<i>3.6b</i>	1	1	1	1	1	-1	1	1	2	1

A section of the variation units key is printed below:

2.9

CARITI QEOU

CWRIS QEOU

3.2

OLW

3.6a

OU

O

OS

The variation units are arranged consecutively, with each reading occupying a separate line. Notice that omission is signified by a blank line, as in the second reading of the variation unit at Heb 3.2. By

comparing the data matrix and the key, it is possible to reconstruct texts at the sampled places. For example, M33 has '0' for units 2.9, 3.2, and 3.6a, implying that its text has CARITI QEQU, OLW, and OU at these places.

CT generates a quasi-transcription of each supplementary text by replacing the UBS4 text with whatever reading is specified by the sample data matrix for each variation unit. The program only constructs texts for the verses in which the corresponding witnesses are extant, as indicated by non-negative matrix entries. The greater part of each constructed text consists of UBS4 text that falls outside variation units. All such text is tagged as reconstructed for the reason given before. *CT* can also be instructed not to write out a constructed text that is comprised of too few variation units to give reliable results in subsequent analysis. Texts constructed from less than five variation units are unlikely to be meaningful when presented as locations on a classical scaling map (see section 6.1.6 below).

Dissimilarity matrices

The classical scaling procedure begins with a dissimilarity matrix that is derived from a data matrix. The present study utilises the principal data matrices generated by the collation program described in the last chapter. (It would also be possible to derive a dissimilarity matrix from the sample data matrix.)

A dissimilarity matrix specifies the dissimilarity of each pair of objects found in the data matrix which forms its basis. Every dissimilarity matrix is square, having the same number of rows and columns. Each dissimilarity in the matrix is calculated from a similarity coefficient. It is easy to be confused by the alternating use of 'similarity' and 'dissimilarity' in this discussion. To avoid confusion, it is worth remembering that the dissimilarity matrix tabulates what are essentially distances between witnesses. The 'distance' between each pair of witnesses is calculated by a two step process. First, the similarity coefficient of the pair is calculated. Second, the complement of the similarity is calculated, resulting in a 'distance' or dissimilarity. Part of the collation output for Heb 1.3 may be used to illustrate the process.

$$w(p) = d(p,1) + d(p,2) + d(p,3) + \dots + 0$$

As the matrix is symmetrical, it is only necessary to show the lower semi-matrix to convey all of the dissimilarity information.

Smilarity coefficients

A variety of similarity coefficients can be employed to compare the objects of a data matrix. In the case of binary data, similarity coefficients are expressed in terms of conventional 2 x 2 contingency table notation (Podani, 1994, 32). If the pair of objects being compared are labelled *R* and *S*, then:

a = no. of variables present in both *R* and *S*;

b = no. of variables present in *R* but not *S*;

c = no. of variables present in *S* but not *R*;

d = no. of variables absent from both *R* and *S*; and,

n = *a* + *b* + *c* + *d* is the total number of variables that exist for *R* and *S*.

In the present case, objects are New Testament *witnesses*; variables are *units* of the synthetic text consisting of distinct words, punctuation, and so on; *a* is the number of times the first and second witnesses in a given pair both have 'ones' for corresponding data matrix entries; *b* is the number of times the first member of the pair has 'one' and the second has 'zero'; *c* is the number of times the first member has 'zero' and the second has 'one'; and *d* is the number of times that both have 'zero'. This last quantity is commonly referred to as the number of double zeros.

Double zeros

Similarity coefficients are divided into two classes: those which take account of double zeros and those which do not. Whether or not to consider double zeros is a vexatious question. Should agreement upon absence be taken to indicate similarity or not?

In some data matrices, double zeros do not indicate similarity. For instance, if a variation unit of the kind found in a critical edition is converted to a binary representation, then a similarity measurement that considers double zeros will produce misleading results. This may be

illustrated by considering the binary representation of a variation unit that was shown before when discussing data types:

	<i>P46</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>	<i>U6</i>	<i>É</i>
<i>1.3a</i>	0	1	1	1	0	<i>É</i>
<i>1.3b</i>	0	0	0	0	1	<i>É</i>
<i>1.3c</i>	1	0	0	0	0	<i>É</i>

As the component readings are mutually exclusive, each witness can only have a single 'one' per variation unit. In this context, double zeros are not reliable indicators of similarity because they can occur whether or not two witnesses have the same reading. The only effective similarity coefficient under these conditions is one that restricts its scope to agreement in presence, as indicated by double ones.

In other data matrices, double zeros play an important part in expressing resemblance. The principal data matrices of this study fall into this category because they are based on a synthetic text rather than mutually exclusive readings. The section of collation output shown before allows the significance of double zeros in this context to be examined:

	<i>P46</i>	<i>U1</i>	<i>U2</i>	<i>U3</i>	<i>U6</i>	<i>U6-1</i>	<i>U6-2</i>
AUTOU	0	1	1	1	1	1	1
DI	1	0	0	0	1	0	1
AUTOU	1	0	0	0	1	0	0

Agreement in absence is significant here because it means that a pair of witnesses both omit the relevant unit, which may be a word, punctuation mark, or format marker. However, the significance of double zeros is variable in these circumstances. They are more likely to indicate relationship between two witnesses that lack a unit found in many other witnesses than when the unit is found in relatively few witnesses.

In summary, double zeros should be considered when expressing resemblance in data matrices based on a synthetic text. Only agreement in presence should be considered when dealing with data matrices that are a binary representation of variation units comprised of mutually exclusive readings.

Smilarity coefficient adopted for this study

As already mentioned, a number of different similarity coefficients are available for expressing resemblance in binary data. The choice of a coefficient is dependent upon the nature of the problem at hand. Podani (1994, 32-46) provides a useful survey of coefficients. They differ by attaching varying degrees of importance to the quantities a , b , c , and d defined before.

In this study, the principal data matrices are comprised of binary data. As the matrices are based on a synthetic text, it is desirable to consider double zeros. The simple matching coefficient suits binary data and takes account of double zeros. It is calculated by dividing the number of matching data matrix entries by the number of units that exist for both witnesses being compared:

$$SMC = (a + d) / n = (a + d) / (a + b + c + d)$$

The Jaccard index may be used should it be desired to ignore double zeros:

$$JI = a / (a + b + c)$$

Percentage agreement is the multistate analogue of the Jaccard index, except for the factor of one hundred required to produce a percentage. As New Testament textual researchers are accustomed to using percentage agreement to express resemblance, the Jaccard index would provide a more familiar measure than the simple matching coefficient. Unfortunately, the Jaccard index is indeterminate if $(a + b + c)$ is zero. This occurs when two witnesses agree in absence for every unit of a data matrix. Such a situation is occasionally encountered in the principal data matrices that deal with spelling variation.

The Russell and Rao index provides a coefficient that might be regarded as a compromise between the simple matching coefficient and the Jaccard index:

$$RRI = a / n = a / (a + b + c + d)$$

This resemblance measure is dependent on the number of double zeros (Podani, 1994, 36). However, its complement does not always satisfy the requirement that the dissimilarity between an object and itself should be zero (Chatfield and Collins, 1980, 195). Also, I have noticed that the percentages of variation accounted for by respective classical scaling dimensions are relatively small when this index is used with my data.

Each coefficient has its own strengths and weaknesses. I have adopted the simple matching coefficient for this study because it is never indeterminate and takes account of double zeros. Besides these reasons, J. C. Gower showed that the results of a popular multivariate analysis technique called principal component analysis are equivalent to those obtained through classical scaling if the simple matching coefficient is used in conjunction with binary data matrices (Chatfield and Collins, 1980, 201).

Only two of the similarity coefficients incorporated in the *SYN-TAX* analysis package can deal with missing data: Gower's general coefficient and the mixed data distance coefficient (Podani, 1994, 16). Gower's general coefficient is equivalent to the simple matching coefficient if double zeros are included or the Jaccard coefficient if they are excluded. The mixed data distance coefficient is equivalent to one called the Euclidean distance coefficient for binary data. The Euclidean distance coefficient is closely related to the simple matching coefficient, so results obtained through one can be expected to be comparable to results obtained through the other (Podani, 1994, 34).

As Gower's general coefficient can be set up to be equivalent to the simple matching coefficient, there is nothing to stop dissimilarity matrices being produced from principal data matrices which incorporate missing data. However, I prefer to eliminate those units for which some witnesses lack data prior to the construction of dissimilarity matrices. Each dissimilarity is then known to be calculated from the same number of units. By contrast, if units affected by missing data are not eliminated and a coefficient which can handle missing data is employed, only the number of units which exist for both witnesses of a given pair enter into the dissimilarity calculation. This number can be relatively small compared with the number of units in the data matrix, and might even be

zero. A dissimilarity that is based on too few units tends to be unreliable, and one that is based on zero units will be undefined, making it impossible for analysis to proceed.

Summary

Classical scaling provides a novel technique for examining the affiliations of New Testament witnesses. It produces maps that simultaneously present all witness relationships. Previously, such a 'picture' of the New Testament textual situation had to be constructed as a mental exercise by comparing two witnesses at a time. There is no guarantee that classical scaling is the best scaling method to use in the context of New Testament texts. For one thing, the assumption that 'distances' between texts are Euclidean requires verification.

The classical scaling demonstration showed that geographical information may be inherent in a table of percentage agreements between New Testament witness readings. However, no correlation between map axes and witness dates was demonstrated.

As far as dissimilarity matrices are concerned, ignoring units affected by missing data avoids the danger of undefined dissimilarities. It also confines calculations to a known number of units. Without this strategy, a calculation could be based on too few units to produce a reliable dissimilarity. If units which contribute nothing to a knowledge of witness relationships are ignored, the extent of dissimilarity calculations will be reduced without affecting the outcome of the classical scaling procedure.

It is preferable to use the simple matching coefficient to calculate resemblances from data matrices that are based on a synthetic text. While it is appropriate to consider double zeros in this context, there are occasions when they should be ignored. One such occasion is when the data of a critical apparatus are presented in the form of a multistate matrix.

Fig. 1: Distances between capital cities of Australia (km)

	<i>P</i>	<i>D</i>	<i>B</i>	<i>S</i>	<i>C</i>	<i>M</i>	<i>H</i>	<i>A</i>
<i>P</i>	0							
<i>D</i>	2747	0						
<i>B</i>	4166	3004	0					
<i>S</i>	3937	3319	742	0				
<i>C</i>	3724	3285	968	273	0			
<i>M</i>	3307	3247	1449	810	537	0		
<i>H</i>	3716	3882	1827	1087	869	628	0	
<i>A</i>	2555	2659	1803	1401	1171	774	1312	0

Fig. 2: Classical scaling map of Australia: Axes 1 and 2

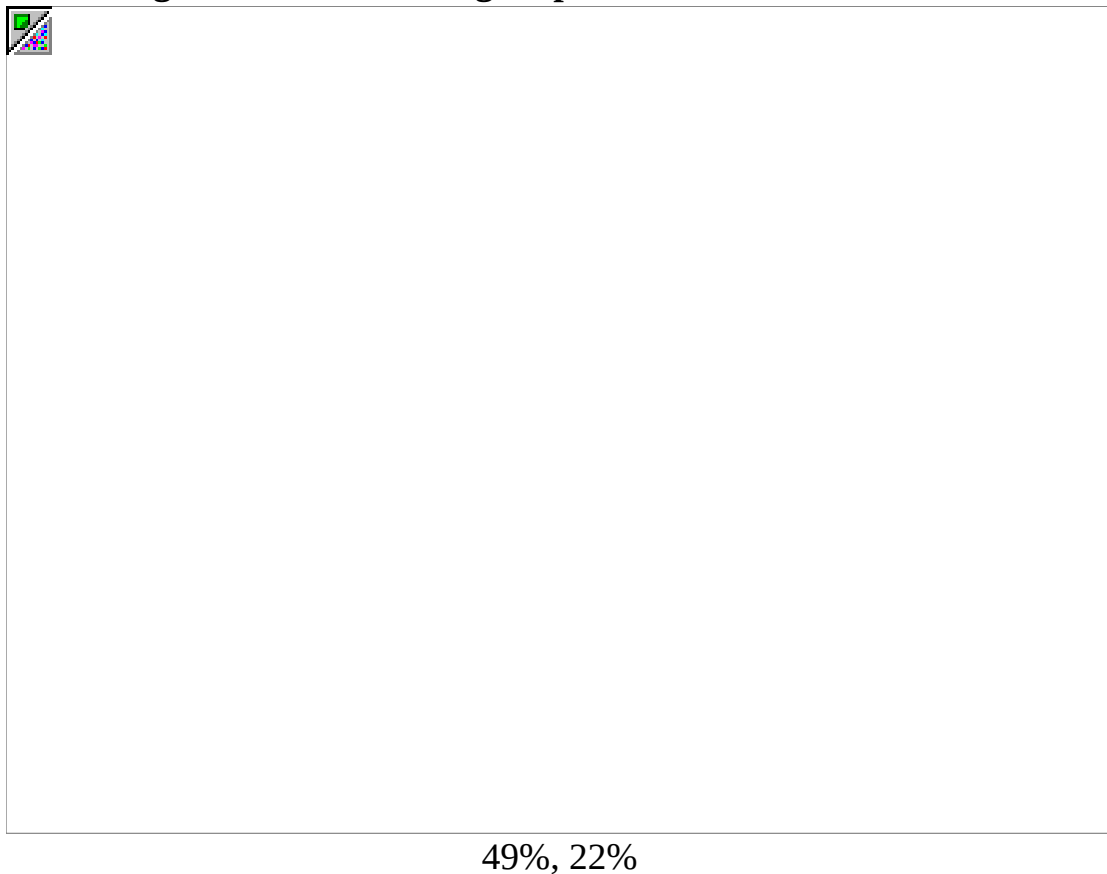


Fig. 3: Classical scaling map of Australia: Axes 1 and 3

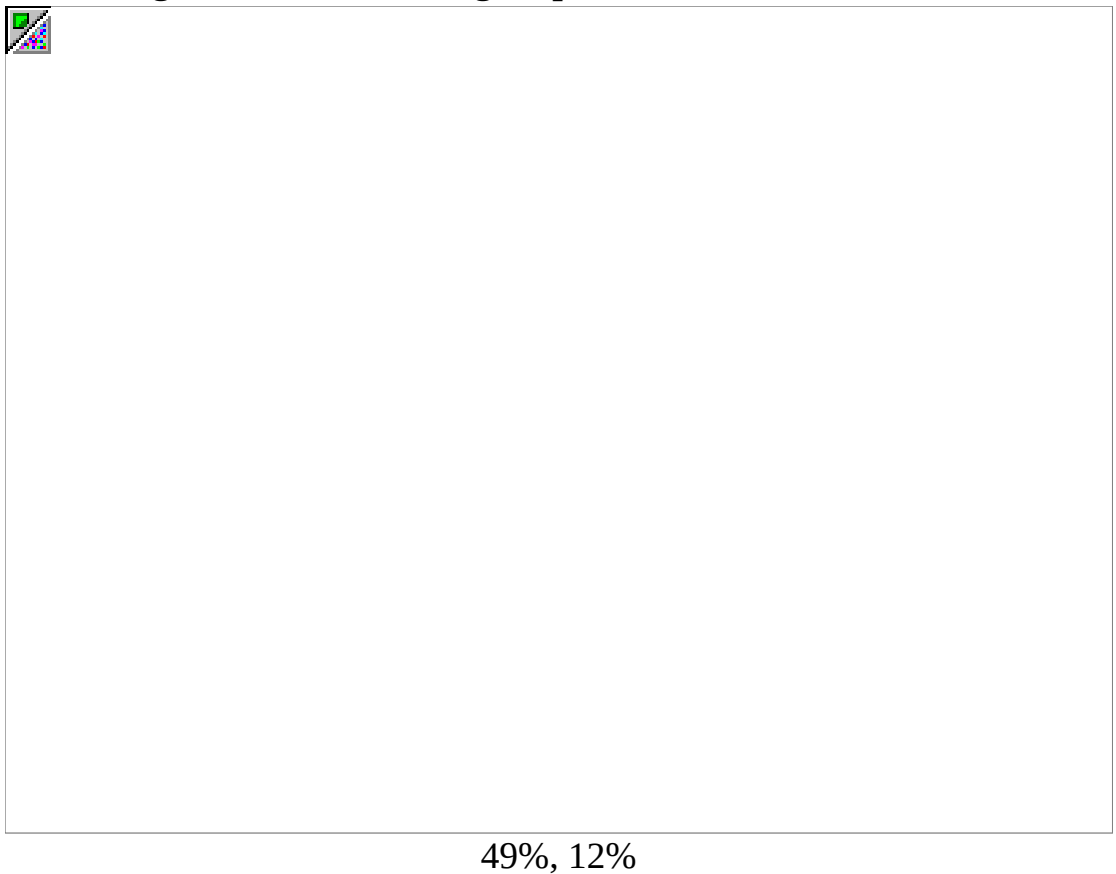


Fig. 4: Dissimilarity matrix for John chapter 4

	<i>TR</i>	<i>P66</i>	<i>P75</i>	<i>U3</i>	<i>U1</i>	<i>U2</i>	<i>U4</i>	<i>U5</i>	<i>U32</i>
<i>TR</i>	0								
<i>P66</i>	39.4	0							
<i>P75</i>	47.5	34.4	0						
<i>U3</i>	49.2	39.4	14.8	0					
<i>U1</i>	69.0	65.6	69.0	67.2	0				
<i>U2</i>	16.4	44.3	41.0	37.7	72.1	0			
<i>U4</i>	44.3	31.1	31.1	29.5	67.2	41.0	0		
<i>U5</i>	55.7	67.2	80.3	83.6	42.6	59.0	73.8	0	
<i>U32</i>	36.0	39.4	44.3	39.4	72.1	50.8	37.7	60.7	0

Fig. 5: Dissimilarity matrix for John chapters 1-8

	<i>TR</i>	<i>P66</i>	<i>P75</i>	<i>U3</i>	<i>U1</i>	<i>U2</i>	<i>U4</i>	<i>U5</i>	<i>U32</i>
<i>TR</i>	0								
<i>P66</i>	49.1	0							
<i>P75</i>	43.5	48.9	0						
<i>U3</i>	47.5	45.7	19.0	0					
<i>U1</i>	65.0	56.3	74.5	73.4	0				
<i>U2</i>	19.9	46.0	43.8	42.4	74.5	0			
<i>U4</i>	36.2	44.4	27.2	31.3	63.8	41.1	0		
<i>U5</i>	62.5	64.2	77.1	77.8	45.9	61.7	70.0	0	
<i>U32</i>	41.6	53.3	41.5	39.7	68.7	48.0	40.0	65.6	0

Fig. 6: Dissimilarity matrix for John chapter 9

	<i>TR</i>	<i>P66</i>	<i>P75</i>	<i>U3</i>	<i>U1</i>	<i>U2</i>	<i>U5</i>	<i>U32</i>
<i>TR</i>	0							
<i>P66</i>	64.7	0						
<i>P75</i>	52.9	49.0	0					
<i>U3</i>	54.9	51.0	21.6	0				
<i>U1</i>	66.7	54.9	37.3	37.3	0			
<i>U2</i>	17.6	54.9	54.9	58.8	68.6	0		
<i>U5</i>	52.9	64.7	74.8	68.6	64.7	64.7	0	
<i>U32</i>	47.1	70.6	33.3	41.2	41.2	54.9	62.7	0

Fig. 7: Classical scaling map for John 4

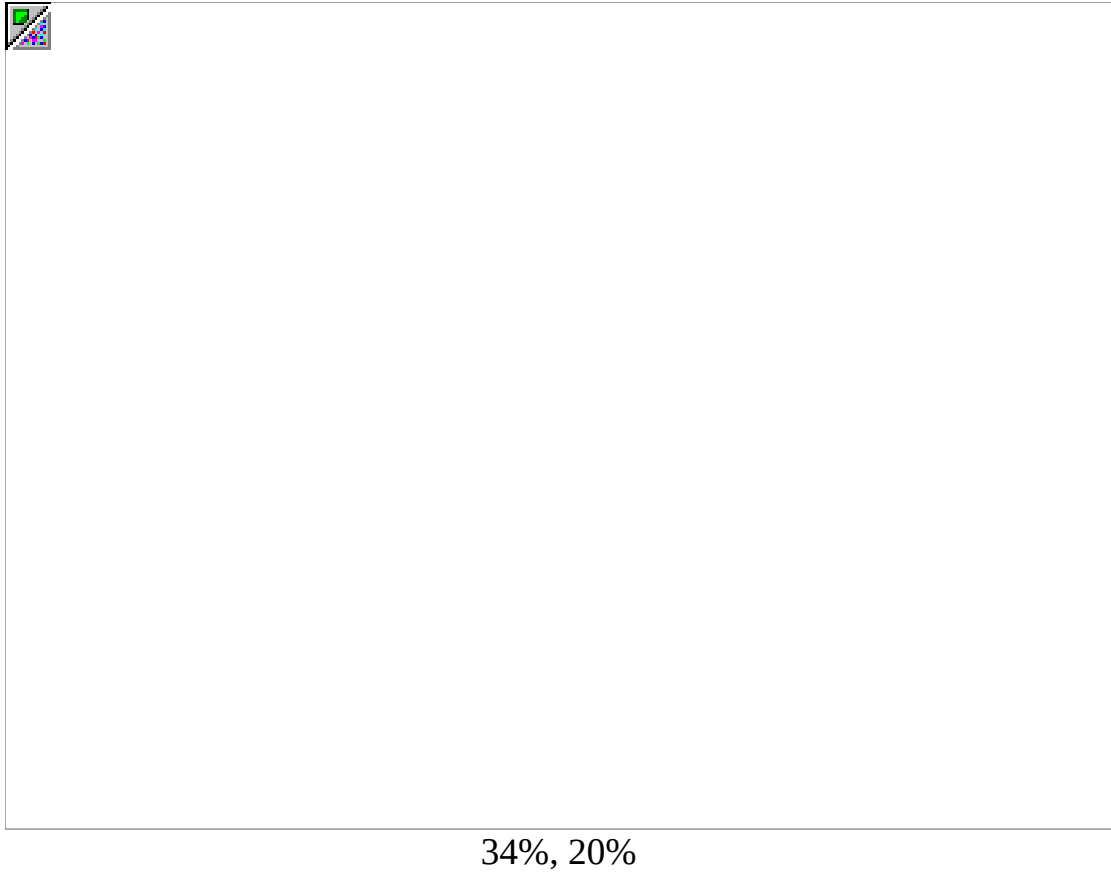


Fig. 8: Classical scaling map for John 1-8



32%, 17%

Fig. 9: Classical scaling map for John 9

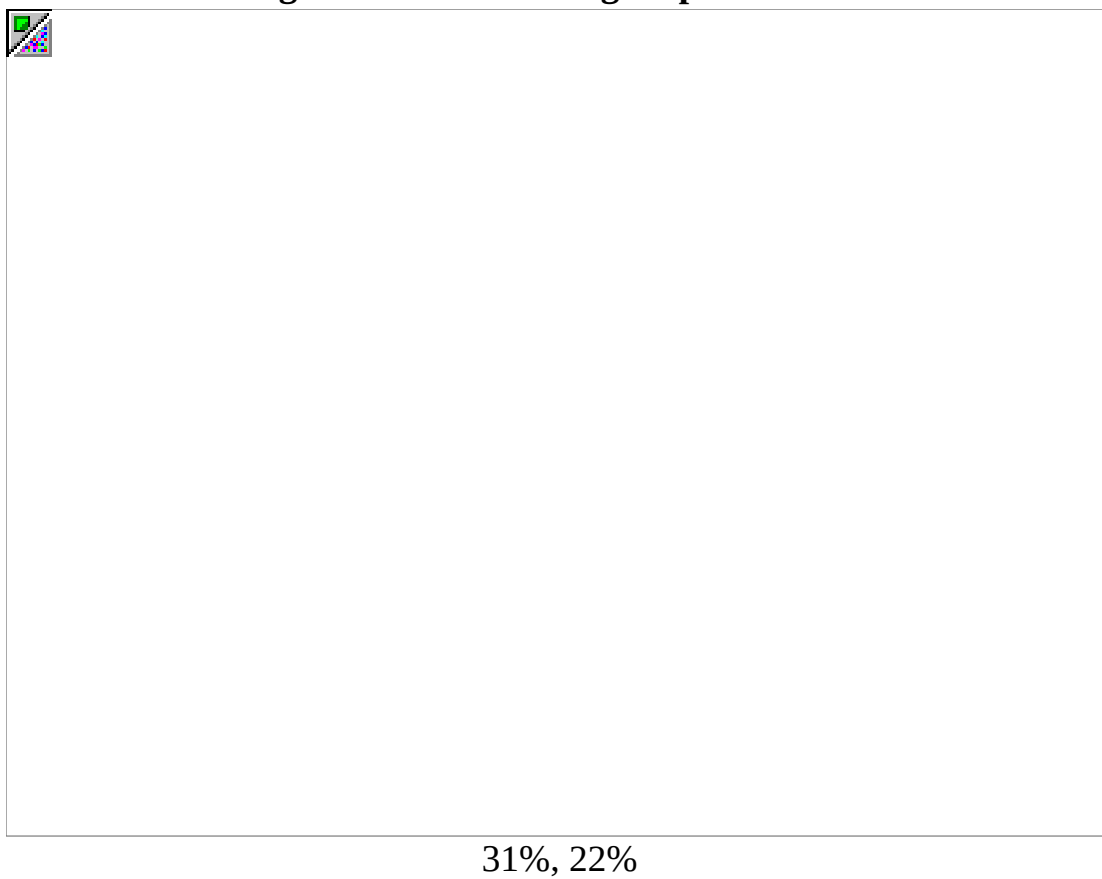


Fig. 10: Church Fathers incorporated as supplementary witnesses

Greek Fathers

Acac	Acacius-Caesarea	365
Antioch	Antiochus	VII
Ath	Athanasius	373
Bas	Basil the Great	379
Chr	John Chrysostom	407
Clem-A	Clement-Alexandria	before 215
Clem-R	Clement-Rome	after 95
Cos	Cosmas	VI
Cyr-A	Cyril-Alexandria	444
Cyr-J	Cyril-Jerusalem	386
Did	Didymus	398
Eus	Eusebius-Caesarea	339
Euth	Euthalius	V
Greg-Ny	Gregory-Nyssa	394
Ir	Irenaeus	II
Isid	Isidore-Pelusium	c. 435
John-D	John-Damascus	before 754
Macar	Macarius/Symeon	IV/V
Or	Origen	253
Phot	Photius	after 886
Procl	Proclus	446
Ps-Ath	Pseudo-Athanasius	VI
Ps-Oec	Pseudo-Oecumenius	VI
Socr	Socrates-Constantinople	after 439
Thdor	Theodore-Mopsuestia	428
Thdrt	Theodoret	c. 466
Thphyl	Theophylact	XI

Latin Fathers

Amb	Ambrose	397
Aug	Augustine	430
Cassiod	Cassiodorus	c. 580
Faustin	Faustinus	IV
Fulg	Fulgentius	533
Jer	Jerome	419
Lcif	Lucifer-Calaris	370
Sedul	Sedulius Scottus	IX
Tert	Tertullian	after 220
Varim	Varimadum	445/480

Syrian Fathers

Ephr	Ephraem-Edessa	373

References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *Novum Testamentum Graece*. Nestle-Aland, 27th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Aland, Kurt and Barbara. 1989. *The text of the New Testament: an introduction to the critical editions and to the theory and practice of modern textual criticism*. 2nd rev. and enlarged ed. Trans. Erroll F. Rhodes. Grand Rapids: Eerdmans.
- Aland, Kurt, Matthew Black, Carlo M. Martini, Bruce M. Metzger, and Allen Wikgren (eds.). 1983. *The Greek New Testament*. United Bible Societies, 3rd corr. ed. New York: United Bible Societies.
- Brooks, James A. 1991. *The New Testament text of Gregory of Nyssa*. Society of Biblical Literature: the New Testament in the Greek Fathers, 2. Ed. Gordon D. Fee. Atlanta: Scholars Press.
- Chatfield, Christopher, and Alexander J. Collins. 1980. *Introduction to multivariate analysis*. London: Chapman and Hall.
- Ehrman, Bart D. 1993. *The Orthodox corruption of scripture: the effect of early Christological controversies on the text of the New Testament*. New York: Oxford University Press.
- Epp, Eldon Jay. 1993a. 'Decision points in past, present, and future New Testament textual criticism'. In *Studies in the theory and method of New Testament textual criticism*. Ed. Eldon Jay Epp and Gordon D. Fee. Studies and documents, 45. Grand Rapids: Eerdmans, 141-173.
- Epp, Eldon Jay. 1995. 'The papyrus manuscripts of the New Testament'.

In *The text of the New Testament in contemporary research: essays on the status quaestionis*. Festschrift in honour of Bruce M. Metzger. Studies and documents, 46. Ed. Bart D. Ehrman and Michael W. Holmes. Grand Rapids: Eerdmans, 3-21.

Fee, Gordon D. 1968. 'Codex Sinaiticus in the Gospel of John: a contribution to methodology in establishing textual relationships'. *New Testament studies* 15/1, 23-44.

Fee, Gordon D. 1993. 'P75, P66, and Origen: the myth of early textual recension in Alexandria'. In *Studies in the theory and method of New Testament textual criticism*. Ed. Eldon Jay Epp and Gordon D. Fee. Studies and documents, 45. Grand Rapids: Eerdmans, 247-273.

Head, Peter M. 1990. 'Observations on early papyri of the Synoptic Gospels, especially on the "scribal habits"'. *Biblica* 71/2, 240-247.

Mealand, D. L. 1995. 'The extent of the Pauline corpus: a multivariate approach'. *Journal for the study of the New Testament* 55, 61-92.

Metzger, Bruce M. 1994. *A textual commentary on the Greek New Testament*. 2nd ed. Stuttgart: Deutsche Bibelgesellschaft.

Milne, H. J. M. and T. C. Skeat. 1938. *Scribes and correctors of the Codex Sinaiticus*. Oxford: Oxford University Press.

Moore, David S. and George P. McCabe. 1993. *Introduction to the practice of statistics*. 2nd ed. New York: W. H. Freeman.

Mullen, Roderic L. 1997. *The New Testament text of Cyril of Jerusalem*. Society of Biblical Literature: the New Testament in the Greek Fathers, 7. Ed. Bart D. Ehrman. Atlanta: Scholars Press.

Petersen, William L. 1994. *Tatian's Diatessaron: its creation, dissemination, significance, and history in scholarship*. Supplements to Vigiliae Christianae, 25. Leiden: E. J. Brill.

Podani, János. 1994. *Multivariate data analysis in ecology and*

systematics: a methodological guide to the SYN-TAX 5.0 package. Ecological computations series, 6. The Hague: SPB Publishing.

Podani, János. 1995. *SYN-TAX 5.02. Mac: computer programs for multivariate data analysis on the Macintosh system.* Computer program and user's guide. Budapest: Scientia Publishing.

Ropes, James Hardy. 1926. *The beginnings of Christianity.* Part 1. *The Acts of the Apostles.* Vol. 3. *The text of Acts.* Ed. F. J. Foakes Jackson and Kirsopp Lake. London: Macmillan. Repr. 1979. Grand Rapids: Baker Book House.

Ross, J. M. 1992. 'Floating words: their significance for textual criticism'. *New Testament studies* 38, 153-156.

Royse, James Ronald. 1981. 'Scribal habits in early Greek New Testament papyri'. Dissertation (ThD). Graduate Theological Union.

Souter, Alexander (ed.). 1947. *Novvm Testamentvm Graece.* 2nd ed. Oxford: Clarendon Press.

Souter, Alexander. 1954. *The text and canon of the New Testament.* Studies in theology, 25. 2nd ed., rev. C. S. C. Williams. London: Gerald Duckworth.

Streeter, Burnett Hillman. 1925. *The four Gospels: a study of origins treating of the manuscript tradition, sources, authorship, & dates.* New York: Macmillan.

Tischendorf, Konstantin von (ed.). 1872. *Novum Testamentum Graece.* Vol. 2. 8th major critical ed. Leipzig: Giesecke and Devrient. Repr. 1965. Graz: Akademischen Druck.

Wachtel, Klaus and Klaus Witte. 1994. *Das Neue Testament auf Papyrus.* Vol. 2. *Die Paulinischen Briefe.* Part 2. *Gal, Eph, Phil, Kol, 1 u. 2 Thess, 1 u. 2 Tim, Tit, Phlm, Hebr.* Arbeiten zur neutestamentlichen Textforschung, 22. Berlin: Walter de Gruyter.

Westcott, Brooke Foss and Fenton John Anthony Hort. 1881b. *The New Testament in the original Greek*. Vol. 2. *Introduction [and] Appendix*. Cambridge: Macmillan. Repr. 1974. Graz: Akademische Druck.

Zuntz, Günther. 1953. *The text of the epistles: a disquisition upon the corpus Paulinum*. Schweich Lectures of 1946. London: British Academy.

INTERPRETATION

Synopsis

Map interpretation

The collation programs produce data matrices that focus on textual, spelling, and other forms of variation among the witnesses of Hebrews. These constitute the basis of classical scaling maps produced with Dr Podani's *SYN-TAX* software. A three-dimensional impression of the data is obtained by use of map-pairs that present the first three classical scaling axes.

Witnesses that appear close together in both maps of a pair can be considered to be closely related. Some regions of the maps tend to be more densely populated than others. Developmental trends can be described in terms of convergence towards a centre, divergence away from a centre, or transition between two centres. There are alternative interpretations for these trends: they may represent either creative development or selection between existing forms.

Axis interpretation

An important part of understanding the significance of the maps is to understand the significance of their axes. The axes are mathematical constructs that serve to differentiate between witnesses in an efficient manner. They can relate to well known quantities or qualities. A set of test witnesses is examined to determine whether their map axes correlate with temporal and geographical measures.

Map interpretation

Once a dissimilarity matrix has been produced, the classical scaling procedure can be performed to produce maps for the witnesses of Hebrews. In practice, J. Podani's *SYN-TAX* software works directly from data matrices, constructing dissimilarity matrices using a specified similarity coefficient, deriving classical scaling witness coordinates for as many map axes as desired, then plotting the maps themselves. The collation program output can be set to construct principal data matrices that are ready for use by the *SYN-TAX* analysis package. Maps that focus on various aspects of the input texts are produced by analysing data matrices that focus on the same aspects. These matrices are generated by appropriate manipulation of the suite of programs described earlier.

Maps that reveal witness affiliations according to three different perspectives are found in the appendices. Each map title identifies the principal witness to which the map refers. The title gives provenance, date, and the name of any individual associated with a particular text, when such details are adequately established. It is important to emphasise that the title information is derived from reference books and not from interpretation of the maps.

Focus on textual variation

Maps that concentrate on textual variation are produced from data matrices that have been extracted by ignoring punctuation and line division, and by levelling spelling variations through the normalisation procedure. The appendix entitled *Textual maps* contains maps for 155 primary and supplementary witnesses. The primary witness maps generally contain fewer witnesses because they usually relate to larger segments of Hebrews than the supplementary witness maps derived from the samples of text represented by the sample data matrix.

Focus on spelling variation

The next appendix contains spelling maps for 62 primary witnesses and seven kinds of spelling variation. Supplementary witnesses were not mapped because their spelling variations had already been levelled in the secondary sources from which they were extracted. In order to obtain the primary witness data matrices, spelling variations were not normalised

and all words with standard spelling were discarded. (Standard spelling is defined by reference to UBS4.)

Data matrices were generated for seven kinds of spelling variation by discarding all but those words relating to each kind in turn. Map-pairs relating to each kind of spelling variation were only produced for the twelve 'complete' primary witnesses that exist for each verse of Hebrews. (The term 'complete' is used with reservation as a witness that exists for all verses of Hebrews can still contain lacunae.) Otherwise, many more maps would have been required to cover each primary witness and every variety of spelling variation. Maps of the seven kinds of spelling variation pertain to both directions of change, except for the *epsilon* to *alpha* *iota* and *alpha* *iota* to *epsilon* spelling transformations that are mapped separately. As with the textual maps, punctuation marks and line-divisions were ignored in all of the spelling maps.

Focus on other kinds of variation

The last maps appendix concerns variations in word-divisions, *kaiv* compendia, line-divisions, and punctuation marks. Each corresponding data matrix was produced by discarding all units that did not relate to the kind of variation under scrutiny. For example, the word-division data matrix was generated by discarding every unit that was not labelled as a word-division variation in the descriptive column appended to the equivalents table used for normalisation. Two of the map-pairs cover verses for which U15 is extant, while the rest relate to the twelve 'complete' primary witnesses of Hebrews.

Punctuation marks and line-divisions were retained to generate the data matrices devoted to these phenomena. The levelled punctuation map-pair was produced by normalising all punctuation marks to a single character. The same strategy was used for the levelled punctuation and line-division map-pair. Otherwise, normalisation was not used, even though the descriptive column of the equivalents table played an essential role in isolating the variants of interest.

Number of axes and explanatory power

I have been content to present only the first three classical scaling axes. This is achieved by printing a pair of maps for each principal witness.

The first map gives axes one and two, and the second map of the pair gives axes one and three. The number of units and the percentages the respective axes contribute to explaining the variation found in the corresponding dissimilarity matrix is printed below each pair of maps.

More axes could be printed. However, to do so would be to go beyond the number that can be comprehended without resorting to quite esoteric devices such as Andrews curves, Chernoff faces, or weather-vane plots (Chatfield and Collins, 1980, 50). In this study, the combined explanatory power of the first three axes is seldom less than fifty percent. In other words, three axes are nearly always sufficient to represent the main part of the variation inherent in the dissimilarity matrices.

Three-dimensional interpretation

As the scale of axis one is always the same in each pair of maps, a three-dimensional impression of the plotted witness positions can be obtained by imagining the second axis to be in a horizontal plane, and the third to be in a vertical plane. Taking the textual map of P13 as an example, this means that U6 would be located somewhere above the page when looking at the upper map, while UBS4 would be below the page.

Number of units

The more units used to calculate similarities, the better the representation of relative witness dispositions in a map. Each witness that appears in the maps has its own pair of principal maps, which should be the first to be considered when studying the allegiances of that witness. This is because the principal map-pair will generally be based on the maximum possible number of units. As missing data has been eliminated, the 'distance' between two witnesses is always calculated from the same number of units as printed below the map-pair being examined.

Maps have not been produced for primary and supplementary witnesses whose data matrices contain less than five units after those units with missing data, singleton variations, and no variation have been discarded. The requirement for a minimum of five units is based on the following reasoning. In the context of a binary data matrix, the units of two completely unrelated witnesses can be expected to agree as often as they disagree. That is, the probability of agreement is equal to the probability

of dissent. As a consequence, the probability of two witnesses appearing in the same location of a classical scaling map by chance is one half raised to the power of the number of units considered, provided the units are independent. For five independent units, two unrelated witnesses can be expected to have the same pattern of variation by chance in about three percent of cases ($1/32 \sim 0.03$). Many probability studies settle for a confidence level of 95% to discriminate against random agreements with the experimental hypothesis. Here, the use of at least five independent units gives a confidence level of more than 95%, while four or less units result in confidence levels below 95%.

This reasoning assumes that the units are independent. However, such is not the case for the textual data matrices of this study. In these matrices, consecutive units have a high probability of being correlated because variant readings often affect a phrase rather than a single word. It is conceivable that a data matrix with five variation units would relate to a single phrase that is present in some witnesses and absent in others. In such a case, the probability of random agreement would be $1/2$ instead of $1/32$. For this reason, complete agreement from a sample of at least five variation units may not be a stringent enough condition for 95% confidence where textual variation is concerned.

Even though two witnesses that agree more often than they disagree should be considered as related, it is sufficient to consider only unanimous agreement when ascertaining affiliation from a small number of units. Closely related witnesses are more likely to exhibit unanimous agreement than distantly related witnesses. On average, therefore, a witness will be better characterised by witnesses exhibiting complete agreement than by witnesses that show partial agreement.

Proximity

Due to the nature of the classical scaling procedure, two witnesses that appear to be relatively close together in the maps will be found to have a relatively high similarity. By the same token, two witnesses that are relatively far apart are relatively dissimilar. That is, proximity implies resemblance. As an illusion of proximity can be created by the orientation of the map axes relative to the witness locations, two witnesses should appear close together in both maps of a pair before they

can be considered similar.

Convergence, divergence, and trajectories

Presumably, all witnesses of Hebrews are descendants of a single original text. This text, if it were known, would have a place in every one of the printed maps because it would exist for all verses of Hebrews. By all reasonable estimates, the mapped witnesses are at least a century removed from the original text. (As Metzger (1992, 265-6) points out, 'we are confronted with several highly improbable circumstances' if Y. K. Kim's first century date for P46 is accepted.) Westcott and Hort (1881b, 93) state that 'all the important ramifications of transmission preceded the fifth century.' If so, the textual maps depict diversification and standardisation which took place within boundaries that did not move to any great extent after the fourth century. The location of the primitive origin is probably within these boundaries, but not necessarily so.

Leaving aside the absolute reference point that would be provided by the original text, the position of a mapped witness can often be understood in relative terms of convergence towards or divergence from centres populated by other witnesses. This perspective is especially useful for witnesses that occupy somewhat unique locations. If such a witness lies on a trajectory from one location to another, it could represent a genuine intermediate stage on a developmental path connecting the locations. Alternatively, the same witness may represent scribal efforts to make one manuscript conform to another. Indeed, a number of the textual maps relating to correctors support the latter interpretation. The fact that there may be no obvious signs of correctional activity in a transitional witness does not detract from this assessment: the witness, or one of its ancestors, could have incorporated corrections to its parent manuscript in a seamless fashion.

What might be called divergent witnesses occupy the periphery of regions populated by extant witnesses. These, also, can be understood in alternative ways. On one hand, they could be the result of creative impulses that drove their texts into uncharted areas. On the other hand, they could lie on a trajectory towards a region that was once populated, but for which there are no longer any extant witnesses. If this were the

case, divergent witnesses would actually be transitional.

The question of which interpretation to prefer is bound up with the nature of variation. If the history of the text is one of selection from diverse primitive forms then transitional texts would be explained in terms of correctional activity. But if the text was characterised by creative development, then transitional and divergent witnesses would represent intermediate developmental stages and endpoints, respectively.

Given that all copies of Hebrews stem from a single autograph, the developmental model must be preferred, at least in the beginning. A rapid growth in the number of variations during the earliest phases of transmission would provide the grounds for the selective model to displace the developmental model as the best way of explaining textual transmission after an early date. This is not necessarily the case, however, as the developmental model may be quite capable of explaining all that is revealed in the maps. Further investigation is needed to decide which model best explains the evidence at different stages. In fact, both models can coexist, so that textual history may be summarised as a struggle for survival of various forms played out against a backdrop of correcting scribes and creative editors who competed to alter the text as they saw fit.

Axis interpretation

The fact that the axes of a classical scaling map are mathematical constructs called eigenvectors does not contribute much to an understanding of their meaning. A more enlightening approach examines their function and searches for association with familiar measures.

Inherent characteristics

Each map axis distinguishes between objects on the basis of an inherent quality or characteristic that is best defined in terms of itself: *the inherent characteristic of a classical scaling axis is that quality of mapped objects which is efficiently differentiated into a range of values along the axis.* To give a practical example of this definition, the inherent characteristic of the first axis in the P46 textual maps is the quality that differs between witnesses such as U56, U142, TR, U151, U18, and

M2815 on the one hand, and witnesses such as P46, U6, U2, and UBS4 on the other. By the same definition, the inherent characteristic of the second axis is related to the textual variations that distinguish witnesses like U56 and U142 from witnesses like U151 and U18.

Association between inherent and familiar characteristics

It is possible for the inherent characteristic of a classical scaling axis to be associated with a familiar quality or characteristic. Texts like those found in the first group of witnesses just mentioned have been called Byzantine, while those of the second group, with the possible exception of U6, have been called Alexandrian. That is, the first axis of the P46 textual maps can be characterised as one which differentiates between Alexandrian and Byzantine witnesses.

It is also possible for the inherent characteristic of an axis not to have a familiar interpretation, as in the second axis of the P46 map. As far as I know, there are no common terms to describe witnesses like U56 and U142 as opposed to witnesses like U151 and U18. Whether or not an axis can be associated with a familiar characteristic depends on whether its inherent characteristic correlates with the familiar one. A test for this kind of correlation can be carried out by reference to mapped objects that are defined both in terms of the inherent and the familiar characteristics.

Correlation with temporal and geographical measures

Resemblance between witnesses of Hebrews may be due to shared circumstances. This is a reasonable supposition, given that two witnesses that originated in a similar environment are more likely to resemble each other than witnesses that originated under disparate conditions, other things being equal. Among circumstances that might be expected to influence resemblance among witnesses are those relating to time and place of origin. In order to test the hypothesis that temporal and geographical measures correlate with particular classical scaling axes, a set of witnesses that are well defined in terms of the axes and the measures is required. Versional and patristic texts are possible candidates for such a set. These texts provide 'snapshots' of the text of Hebrews as it existed in particular times and places.

Unfortunately, this kind of evidence suffers from certain weaknesses.

The dates and provenances of versions are often subject to doubt, while patristic citations are limited by phenomena such as adaption to context by the Church Fathers. In addition to this, the number of units upon which their maps are based is often quite small, making the information they convey correspondingly less certain. Nevertheless, these test witnesses are superior to other classes of evidence when it comes to furnishing texts that can be directly associated with specific localities and times.

Derived coordinates

The test witnesses are not coextensive for Hebrews, so they do not all occur in the same maps. As a consequence, there is no direct way to use them to measure the correlation of a given set of classical scaling axes with temporal and geographical dimensions. Instead, a number of steps are required to derive coordinates for the test witnesses that relate to the classical scaling axes under scrutiny. First, a set of reference axes is selected by choosing a particular map-pair to be the basis of further investigation. This reference map-pair will contain its own set of witnesses, hereafter called reference witnesses. Next, the position of each test witness is defined relative to the reference witnesses by examining the test witness dissimilarity matrices. Finally, the test witness coordinates relative to the reference axes are estimated from the reference witness coordinates.

There are 31 'complete' sampled witnesses that are extant for all of the sample variation units. Each one has an identical map-pair because each one has the same dissimilarity matrix. I have selected the axes of this common map-pair to be the reference axes. As a consequence, the 31 'complete' sampled witnesses are the reference witnesses. Most of the test witnesses are quasi-transcriptions generated from the sample data matrix. The data matrix of a 'complete' sampled witness is based on 71 units. As the number of units in a test witness approaches this maximum of 71 units, its classical scaling axes become more comparable with the reference axes.

In order to derive the coordinates of a test witness, the corresponding dissimilarity matrix is examined to identify its closest three reference witnesses. The coordinates of the three reference witnesses are then

averaged within each dimension to produce coordinates that pertain to the reference map-pair. This is not the only procedure by which the coordinates could be determined. More or less of the closest reference witnesses may be used, but three can be expected to give a representative position. Also, weighted averages that reflect the relative proximities of the nearest neighbours could be employed.

It is important to note that the derived coordinates are only estimates of the 'true' coordinates that a test witness would have if it existed for all 71 units. The averaging procedure tends to centralise the resulting coordinates. Also, the smaller the number of units upon which a test witness dissimilarity matrix is based, the larger the uncertainties in its dissimilarities. There is a corresponding uncertainty concerning which reference witnesses are closest to the test witness.

Fig. 1 gives the three closest reference witnesses and derived coordinates for each test witness. In some cases the dissimilarities of a number of reference witnesses were tied. These ties were resolved by selecting the two most extreme members of the tied group with respect to first axis coordinates in the reference map-pair. If all three of the closest witnesses had to be chosen from a tied group, the third was selected so as to be representative of the entire group or the next closest reference witnesses, with respect to the first reference axis once again.

Test witnesses are included in the table if their approximate dates and localities are known. (Old Latin versions are excluded as each may represent a distinct translation of unknown date.) Authorities supporting the given dates are recorded in the appendices. For Church Fathers, the dates are estimated times of literary activity ascertained from entries in *The Oxford dictionary of the Christian Church* (1997). The latitudes and longitudes are expressed as decimal degrees and are derived from the *Atlas zur Kirchengeschichte* (1987), the *Atlas of the Roman world* (1982), and *'The Times' atlas of the world* (1990).

The maps shown in figs. 2 and 3 are plots of the derived coordinates for the test witnesses. A number of other witnesses are included to make these maps directly comparable with maps of 'complete' sampled witnesses.

Test witness correlations

The following tables present correlations between the test witness derived coordinates and their date, latitude, and longitude estimates:

Correlations for Versions

	<i>Axis 1</i>	<i>Axis 2</i>	<i>Axis 3</i>	<i>Points</i>	<i>Excluded outliers</i>
<i>Date</i>	-0.359	0.523	-0.421	10	Slavonic
<i>Lat.</i>	-0.479	0.424	-0.589	10	Ethiopic
<i>Long.</i>	-0.192	0.340	-0.446	10	Slavonic

Correlations for Church Fathers

	<i>Axis 1</i>	<i>Axis 2</i>	<i>Axis 3</i>	<i>Points</i>	<i>Excluded outliers</i>
<i>Date</i>	-0.139	-0.138	0.010	15	John of Damascus, Theophylact
<i>Lat.</i>	0.030	0.011	-0.027	17	-
<i>Long.</i>	-0.290	0.630	-0.699	14	Ambrose, Augustine, Cassiodorus

The *t*-test procedure which is about to be applied assumes that the variables under consideration are normally distributed. The dates, latitudes, longitudes, and derived coordinates of the test witnesses have anything but normal distributions. Fortunately, 't' procedures are quite robust against nonnormality of the population except in the case of outliers or strong skewness' (Moore and McCabe, 1993, 510). In the interests of reliability, test witnesses with outlying (i.e., comparatively extreme) date, latitude, and longitude values have been excluded from the respective correlation coefficient calculations. Even so, the data still exhibit a skewness that could invalidate the results.

The largest correlation coefficient in the versions table is -0.589. (Only the absolute value is of importance here, so the 'negative' sign can be ignored.) A *t*-test shows that a coefficient of this magnitude can be expected to happen about once in thirteen times where uncorrelated normally distributed variables are concerned, given a sample size of ten points. This is not quite infrequent enough for us to be confident that the correlation is statistically significant. However the fact that none of the correlation coefficients in this table fall close to zero is hard to explain if

the variables are uncorrelated. (With this sample size, the chance of obtaining a correlation coefficient with an absolute value as large as 0.340 is 0.339. Binomial theory then estimates the probability of obtaining eight or nine out of ten correlations of 0.340 or more to be about one in a thousand.)

The Church Fathers table contains a correlation coefficient of -0.699. A coefficient of this magnitude can only be expected to happen by chance less than one time in a hundred, given a sample size of fourteen. Therefore, we can be confident that longitude data correlates with axis 3 coordinates for patristic data. The same goes for axis 2 coordinates as well.

This statistical test has shown that the reference map-pair axes do correlate with temporal and geographical measures for the test witness data. The apparent lack of correlation with the date and latitude measures in the patristic witnesses is somewhat puzzling, but may be due to actual associations being obscured by the indirect plotting procedure or errors related to small sample sizes. Also, textual mobility can result in a Church Father in one locality using a text from a different place and time, thereby upsetting the analysis.

Many of the difficulties experienced in this procedure are caused by the small sample sizes. On this account, further work to establish the texts of Church Fathers, particularly the earlier ones, is most welcome. As more of their texts are analysed, more reliable measurements of their textual affiliations will be possible. The indirect procedures of this study could then be replaced by direct comparison. The possibility of mobile texts still presents a problem that is not solved by a more comprehensive sample. Perhaps a study based on large samples of the texts of early Church Fathers will reveal a strong enough pattern of geographical association to be able to isolate Fathers who used exotic texts.

Summary

The classical scaling maps produced for this thesis focus on textual, spelling, and a few other forms of variation. The analysis extracts a number of dimensions from the corresponding dissimilarity matrices.

Due to the practical limitation of human perception, only the three most important dimensions are displayed in my maps. This allows the observer to gain a three-dimensional impression of the data.

A pair of maps is produced for each principal data matrix of the primary and supplementary witnesses that has five or more units. In addition, map-pairs that relate to other kinds of variation are produced for the 'complete' primary witnesses and for U15. The position of a witness relative to other plotted witnesses reflects its relationships to those witnesses. Proximity implies resemblance. Directions of development are indicated by convergence and divergence relative to other locations.

The map axes are mathematical constructs that point along directions of maximum variation. The meaning of these axes can be better understood if they can be related to more familiar characteristics. A test based on 'complete' sampled witnesses shows that temporal and geographical measures appear to display a correlation with the first three axes. In general, the data are not comprehensive enough to determine the specific nature of this correlation. The only statistically significant correlations are obtained from data relating to the Church Fathers. These show that longitude is correlated with the second and third classical scaling axes for this data.

Fig. 1: Derived coordinates of test witnesses

<i>Name</i>	<i>Place</i>	<i>Date</i>	<i>Lat.</i>	<i>Long.</i>	<i>Axis 1</i>	<i>Axis 2</i>	<i>Axis 3</i>	<i>Closest reference witnesses</i>
Armenian	Armenia	410	40.18	44.28	0.177	-0.097	-0.036	Merk, Souter, Vogels
Bohairic	N. Egypt	300	31.00	31.00	-0.089	-0.14	0.153	M2127, M81, M256
Fayyumic	Fayyum	325	29.50	30.50	-0.077	-0.116	0.122	M2127, M256, Von Soden
Sahidic	S. Egypt	200	28.00	31.00	0.203	-0.069	-0.028	Von Soden, Tischendorf, Bover
Ethiopic	Ethiopia	500	14.17	38.75	-0.156	-0.113	0.154	M256, U25, M2127
Georgian 1	Georgia	425	41.72	44.80	-0.246	0.001	-0.112	M1962, TR, U56
Georgian 2	Georgia	600	41.72	44.80	-0.244	0.047	-0.183	TR, U18, M2815
Slavonic	Sirmium	884	44.98	19.65	-0.257	-0.002	-0.103	U142, U56, M1962
Harklean	Enaton	616	31.22	29.92	-0.242	0.004	-0.121	M2815, M1962, U56
Palestinian	Palestine	550	31.70	35.20	0.189	0.041	-0.067	Attridge, Tasker, U150
Peshitta	Syria	305	37.13	38.75	-0.187	0.024	-0.097	U18, M1739, M2815
Ambrose	Milan	380	45.47	9.20	0.242	-0.005	-0.061	Attridge, Souter, Tasker
Athanasius	Alexandria	350	31.22	29.92	-0.179	-0.033	0.083	M1881, M365, M1739
Augustine	Hippo	410	36.92	7.78	-0.148	0.027	-0.087	Von Soden, U56, U151
Cassiodorus	Vivarium	550	38.43	16.57	-0.102	-0.084	0.076	U2, M1962, U25
Chrysostom	Antioch	390	36.20	36.17	-0.272	0.013	-0.146	TR, U56, U142
Clement	Alexandria	200	31.22	29.92	0.121	0.017	-0.090	W&H, NA25, M2815
Cyril	Alexandria	430	31.22	29.92	0.075	-0.095	0.062	U25, M81, Von Tischendorf
Cyril	Jerusalem	350	31.78	35.22	-0.034	-0.025	-0.013	TR, UBS4, U25
Didymus	Alexandria	350	31.22	29.92	0.253	-0.026	-0.034	NA25, Vogels, W&H
Ephraem	Edessa	360	37.13	38.75	-0.092	-0.007	-0.119	TR, Von Tischendorf, U56
Eusebius	Caesarea	320	32.50	34.90	-0.188	-0.037	-0.015	M2815, U25, M1881
Gregory	Nyssa	380	38.63	34.72	-0.034	-0.025	-0.013	TR, UBS4, U25
Jerome	Bethlehem	390	31.70	35.20	0.038	-0.030	-0.043	Attridge, M2815, M81
John	Damascus	730	33.50	36.32	-0.272	0.013	-0.146	U56, U142, TR
Origen	Caesarea	230	32.50	34.90	-0.165	-0.079	0.093	M1739, M1881, M104
Theodoret	Cyrrhus	430	36.55	36.85	-0.244	0.047	-0.183	TR, M2815, U18
Theophylact	Ohrid	1090	41.10	20.82	-0.156	-0.113	0.154	U25, M256, M2127

Fig. 2: Derived test witness coordinates: Axes 1 and 2



Fig. 3: Derived test witness coordinates: Axes 1 and 3



References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Atlas of the Roman world*. 1982. Ed. Timothy Cornell and John Matthews. Oxford: Phaidon Press.
- Atlas zur Kirchengeschichte: die christlichen Kirchen in Geschichte und Gegenwart*. 1987. Ed. Hubert Jedin, Kenneth Scott Latourette, and Jochen Martin. Freiburg: Herder.
- Chatfield, Christopher, and Alexander J. Collins. 1980. *Introduction to multivariate analysis*. London: Chapman and Hall.
- Metzger, Bruce M. 1992. *The text of the New Testament: its transmission, corruption, and restoration*. 3rd enlarged ed. New York: Oxford University Press.
- Moore, David S. and George P. McCabe. 1993. *Introduction to the practice of statistics*. 2nd ed. New York: W. H. Freeman.
- The Oxford dictionary of the Christian Church*. 1997. 3rd ed. Ed. F. L. Cross and E. A. Livingstone. Oxford: Oxford University Press.
- 'The Times' atlas of the world*. 1990. 8th comprehensive ed. London: Times Books.
- Westcott, Brooke Foss and Fenton John Anthony Hort. 1881b. *The New Testament in the original Greek*. Vol. 2. *Introduction* [and] *Appendix*. Cambridge: Macmillan. Repr. 1974. Graz: Akademische Druck.

RESULTS

Synopsis

Besides revealing concentrations of witnesses and developmental trends, classical scaling maps show that the relative locations of certain manuscripts depend on whether they are viewed from the perspective of textual or spelling variation. In these respects, the maps present fresh insights into New Testament textual history. Every one of the maps has its own story to tell. Taken together, they speak of more universal things.

Textual maps

The textual maps provide a foundation from which investigation of other classes of maps can be launched. A partition of witnesses into three groups is evident in these maps.

Spelling maps

The same partition into three groups holds for the spelling maps as well. Many witnesses have the same affiliations in spelling and textual maps, but others do not. First steps are taken towards a working theory that might explain this phenomenon.

A postulated link between spelling and locality calls for the three groups to be associated with geographical regions. Evidence linking grouped manuscripts with a particular region is clear in one case, but quite vague in the other two. Nevertheless, a scheme of association is suggested.

Other maps

Maps pertaining to peripheral characteristics such as the locations of word-divisions, *kaiv* compendia, line-divisions, and punctuation marks present a different picture to textual and spelling maps. They reveal relationships that are sometimes surprising and at other times perplexing. Additional causes of agreement are suggested to account for unusual patterns of affiliation among peripheral features. One assumes the existence of rules relating to the features, while the other pertains to agreement by coincidence.

Correctors

A dynamic view of correctors is presented within the context of the three text and spelling groups already identified. Close examination of each corrector's movements reveals insights into the history of the associated manuscript. General trends in textual preferences are evident as well.

Minuscules

Witnesses derived from the sample data matrix are also analysed. They are classified according to a scheme that assumes the three groups seen before apply for sampled witnesses. The minuscules are distributed in a manner that is, for the most part, to be expected.

Versions

The versions are arranged according to date and textual group in order to observe any trends that might have prevailed. Conventional assessments of their texts are compared with assessments arising from the maps. In many cases these agree. Furthermore, the historical circumstances of the versions are often reflected in the maps.

Church Fathers

When the Church Fathers are arranged in the same manner as the versions, there is no clear temporal trend regarding textual grouping. By contrast, there does appear to be a link between geographical locality and textual group.

Authors and editions

The positions of modern authors and editions provide reference points that indicate where the original text should be expected to lie. Nearly all authors and editions lie in the same textual region.

Criteria

In the same way, critical principles provide pointers to the original text. Most of them indicate that the original text lies in the same region as indicated by the authors and editions.

Textual maps

As a first step, I will make a tentative classification of the primary witnesses (i.e., those witnesses that have been transcribed in full) whose

textual maps are based on more than fifteen units. Maps with less than fifteen units are not considered as they are adversely affected by uncertainties associated with small sample sizes. Three broad groups are evident in the maps:

- (1) U18, U20, U56, U75, U122, U142, U151, M2815, TR
- (2) P13, P46, U1, U1s, U2, U3, U4, U6, U15, U16, U48, U243, UBS4
- (3) U25, U44, U75s, U150

The groups delineated here, if they can be called groups, are particularly clear in the textual map of U3, which relates to the first nine chapters of Hebrews alone. This kind of classification is meaningless unless the respective groups definitely exist. What appear to be groups may, in fact, be no more than apparent clusters in a random distribution of objects. (See, for example, the map generated by a planar Poisson process in Chatfield and Collins, 1980, 218.) Even if the groups are real, the number of groups is not certain and it is difficult to classify witnesses with divided allegiances. Questions of group existence, definition, and membership will be addressed in the next chapter. For now, let us assume that the partition just given is a valid one.

The first group is not terribly compact, with the U56-U142 and U18-U151 subgroups being distinct from more central manuscripts such as M2815. It may be that the third group should be described as a subgroup of the second group, or that U56 and U142 should be considered to be a fourth group.

The second group also displays diversity within its unity. In maps which cover all of Hebrews, U6 tends to be separated from U2 and UBS4 along the third axis. The same tendency is exhibited by P46, but to a lesser extent. This tendency is not as pronounced in the P13 map-pair, where P46 appears to be more akin to U2. The same map-pair shows that P13 shares the tendency towards U6 shown by P46. The shift in the relative position of P46 may be due to block mixture, with its text being less similar to U6 in the parts of Hebrews covered by P13. The tendency towards U6 shared by P13 and P46 indicates that if P13 were complete, it would be more similar to P46 than indicated by the P13 maps as they now stand.

The first map of the U3 pair appears to show that P46, U3, and U6 form a tight cluster. This is not a valid conclusion as two witnesses should be close in both maps of a pair before they can be considered to resemble each other. Once the other member of the map-pair is examined, it becomes clear that U6 is somewhat removed from U3 and P46, which are quite similar to each other. The text preserved in U6 shows itself to be unique in the way that it defies close association with any of the other witnesses in its region. In the U3 maps, the P13 maps, and the maps of 'complete' witnesses such as P46 and U2, it never forms a tight affiliation with another witness in both maps of a pair.

On the subject of similar texts, the U1 maps are surprising because they show that the U1 and U2 texts are almost identical. This does not hold for the supplementary folios of Hebrews copied by another scribe of Codex Sinaiticus, designated by Tischendorf as scribe 'D' and designated as U1s here. The corresponding maps show that the U1s text is closer to the texts of P46, U3, and U6. It seems that the exemplar used for these supplementary folios was different from that used for the rest of Hebrews. It would be interesting to compare maps for the respective scribes in other books of the New Testament to see whether the alternate associations persist. There are seven places where Tischendorf's scribe 'D' has copied parts of the New Testament (Milne and Skeat, 1938, 105-111). The rest of the New Testament was copied by the scribe designated 'A'.

The same method of characterising one witness by its position relative to other witnesses can be applied to all witnesses. I encourage the reader to explore the textual maps, mindful of the interpretive approaches discussed before. Maps relating to correctors and those witnesses constructed from the sample data matrix may be ignored at this stage, as they will be discussed below under separate headings.

Spelling maps

Spelling maps have been produced for the primary witnesses as well. A partition into three groups is evident in the spelling perspective as in the textual perspective. (See, for example, the U3 spelling map-pair.) The

witnesses are distributed among spelling groups as follows:

- (1) U4, U56, U75s, U122, U142, U151, U243, M2815, TR, UBS4
- (2) P13, P46, U1, U1s, U2, U3, U6, U16
- (3) U15, U18, U20, U25, U44, U48, U75, U150

Upon comparison with the textual groups, it becomes apparent that witnesses such as P13, P46, U1, U1s, U2, U3, U6, U16, U25, U44, U56, U122, U142, U150, U151, M2815, and the *Textus Receptus* (TR) have the same affiliations in both the spelling and textual maps. Others such as U4, U15, U18, U20, U48, U75, U75s, U243, and the United Bible Societies' fourth edition (UBS4) have different affiliations according to whether the textual or spelling perspective is considered. That is, spelling and text conform to differing standards in about one third of the primary witnesses.

How should this phenomenon be explained? As a first step towards a working theory, heredity can be used to account for textual resemblance between witnesses. Shared readings are attributed to shared archetypes so that community of readings implies common ancestry. Potentially variable readings persist across manuscript generations due to conservative copying practices. Centres of higher witness density might then be regarded as corresponding to primitive archetypes.

Heredity allows for the transfer of readings between manuscripts but not for the development of novel readings. B. H. Streeter's theory of local texts (1925, 37-39) provides one way to account for primitive archetypes. According to his theory, distinctive texts developed in early Christian population centres at a time when the centres were relatively isolated from each other.

So far, the theory can cope with distinct groups of related witnesses, but not differing patterns of affiliation in the textual and spelling perspectives. It remains to explain how a witness could shift from one spelling group to another while remaining in the same textual group. To this end, I propose that textual peculiarities were more likely to be conserved than spelling peculiarities when a manuscript was copied. According to this proposition, if an exotic manuscript (i.e., one imported

from a distant place) was copied, the text of the resultant copy would remain relatively close to its exotic exemplar, while its spelling would be assimilated to the local standard. If this explanation is valid then a witness with different affiliations in the textual and spelling perspectives is the result of a text from one locality being copied in another part of the world.

This proposition assumes: (1) textual mobility; (2) differential copying practices; and (3) localised spelling practices. As far as the mobility of texts is concerned, Eldon Jay Epp (1993b, 280-281) surveys evidence that the transport of people and papyrus documents was commonplace in the Roman world. By implication, the same applies to New Testament manuscripts, thereby providing for the possibility of exotic exemplars.

Why would a scribe treat textual peculiarities differently to spelling peculiarities? Given that spelling varied from place to place in the ancient world, every scribe's spelling faculty would have a particular tendency that developed along the lines of local custom. As the scribe copied, exotically spelled words would immediately stand out as peculiar. According to Metzger (1992, 16), copying entailed four fundamental operations: reading aloud, remembering, dictating aloud, then writing. Adding or deleting a few letters to alter the spelling would do little to disrupt the process. This ease of change would significantly diminish the chances of a peculiar spelling being transferred from exemplar to copy intact. If the exemplar was read aloud, either by a lector or the copyist, and the corresponding words written down using phonetic spelling, the levelling of spelling variation would have been virtually automatic. (Indeed, it is possible that phonetically spelled manuscripts reveal ancient scribal accents.)

Peculiar texts would be less prone to change. Assuming a single exemplar, the copyist would have to be intimately familiar with a standard text before being able to recognise a peculiar one. There is little doubt that there were local standard texts and that scribes could memorise whole books of the New Testament. This would make possible the immediate detection of unusual texts. Even so, I think that it is fair to say that a facility of textual 'total recall' would have been less common than an ability to spell according to local custom. This is especially true

for the earlier phases of New Testament manuscript production, when scribes would have been less familiar with the texts they were copying.

Given that a scribe could recognise exotic texts, he or she would still have to choose what to write down when confronted with a variant. Just how he or she would decide is a matter of scribal psychology. If the scribe were a monk, he would be careful to avoid trouble with his overseer. Some overseers would prefer the standard text, while others would prefer the more ancient one, as the famous marginal note at Hebrews 1.3 in Codex Vaticanus proves. (A translation of the note appears later in this chapter.) Another scribe, knowing that textual variation happened, might get up and consult one or two other manuscripts to establish what the text should be.

Similar considerations apply where manuscripts were produced by dictation. Coming upon a textual variation, the lector would have to decide whether to hold up the production process while consulting other manuscripts for the most authoritative reading, to make a quick decision on the best reading, or even to give the copyists a choice of what to write. Milne and Skeat (1938, 57) give an illustrative example from 1 Maccabees 5.20 in Codex Sinaiticus, where a lector seems to have placed the burden of choice on the copyists, only to have one of them write down exactly what was dictated:

The only reasonable explanation seems to be that the reader, unable to decipher the numeral in the exemplar, called out 'either six or three thousand', and that the scribe mechanically reproduced the remark.

This is an exceptional case, and it is reasonable to expect that the less troublesome course of conserving the exemplar's reading would have been followed unless the reading was particularly disturbing to the lector.

We can assume that the behaviours of those involved in the copying process would have conformed to the principle of least effort, as enunciated by George K. Zipf (1949, 543) in the conclusion to his book *Human behavior and the principle of least effort*:

As to what we have done, we have presented a large number of

observations from a truly wide range of living phenomena; this is the empiric aspect of our study, in which we can claim in all modesty to have presented some empiric laws of wide implications. Then each of these different kinds of empiric laws we have attempted to rationalize; this is the analytic aspect of our study. Finally, all these different rationalizations we have attempted to synthesize in terms of a single unifying principle. That is what we have done.

Our reason for doing so was to establish the single unifying principle Ñ the Principle of Least Effort Ñ which is defined as meaning that each individual will adopt a course of action that will involve the expenditure of *the probably least average of his work* (by definition, *least effort*). That is why we have done what we have done.

In general, textual alterations would have been more costly than spelling alterations in terms of risk or exertion. It follows that spelling peculiarities would have been more volatile than textual peculiarities in the hands of a typical scribe.

This assertion is supported by the maps, which show that clustering is better defined in the spelling perspective than in the textual perspective. The greater dispersion in the textual perspective can be taken to indicate that textual variation was not levelled as readily as spelling variation. The first spelling group is particularly dense, which implies that a strict spelling rule was obeyed by its copyists. Neither the second nor third regions are as well defined. This could imply that the associated scribes were less careful about spelling. On the other hand, their spellings may once have been just as uniform as the group 1 spelling, only to be blurred by some undisciplined copying.

The third assumption of my proposition is not without support. Kirsopp Lake (1906, 4) saw a link between spelling and locality when he wrote, 'mistakes in spelling, especially if repeated, often give a hint as to the pronunciation, and so nationality, of the scribe.' Moulton and Howard (1928, 41-42) wrote,

It is probable that considerable differences existed between the Greek of Rome and Asia, Hellas and Egypt. The pronunciation of i/-iv/ A.D. is a

matter of great importance from its bearing on textual criticism. If we could delimit the localities affected by certain variations, we should have important evidence for the localising of textual types. Unhappily our information is too scanty to make this a really useful resource.

Classical scaling maps may provide the desired means to delimit localities. They suggest the existence of three major centres, and a small leap of faith connects these centres with geographical centres.

If the postulated link between spelling and locality is valid then a primary task is to name the localities associated with the three kinds of spelling. It is not too difficult to find localities that are consistent with the witnesses occupying two of the three regions; the first group can be associated with Constantinople and the second with Egypt. The Egyptian connection is primarily based on the fact that P13, P46, and U16 were found there. Codex Alexandrinus has annotations that connect it with Alexandria (Ropes, 1926, li-lij). Manuscripts such as U3 and U1 have also been associated with Egypt, although the reasons for suspecting that U1 is Egyptian are not as strong as for U3 (Ropes, 1926, xxxiv-xxxvi, xlvj-xlviii; see also Milne and Skeat, 1938, 69, who prefer Caesarea for U1).

One factor that goes against the identification with Egypt concerns the Euthalian divisions shared by codices Sinaiticus, Vaticanus, and the two Vulgate manuscripts Amiatinus and Fuldensis. Milne and Skeat (1938, 38) attribute the relevant section numbering in Sinaiticus to the scribe who copied the New Testament (i.e., scribe 'A'). Hort regarded the corresponding numerals in Vaticanus as very ancient (Westcott and Hort, 1881b, 266), but Lake (1911, xiv) was inclined to date them in the eighth century. Dates aside, Zuntz (1945, 87) wrote that 'The common centre influencing 'Euthalius', the great Uncials, and the Vulgate can hardly have been any other but Caesarea.' This is an important observation that might require the hypothetical geographical boundaries of the second group to be extended to include Palestine. There remains the possibility, however, that the Euthalian sections were known in Egypt before the time of Vaticanus and Sinaiticus, and spread to Caesarea in time to be independently incorporated into the Vulgate manuscripts.

None of the first spelling group members is known to have originated in Constantinople, as far as I know. Nevertheless, they display strict spelling conformity, generally late dates, and their text is called Byzantine. Tischendorf thought that Ephraem's sermons were copied onto U4 at Constantinople (Ropes, 1926, lv). If U4 had remained in the same place since its creation, then its spelling can be taken as additional support for linking Constantinople with the first spelling group. It is possible that this spelling variety should be associated with another copying centre such as Antioch in Syria, although the late dates would seem to be against Antioch.

There is no compelling evidence to link the manuscripts of the third spelling variety with a particular location. Any attempt to associate these eight manuscripts with a locality depends on circumstantial evidence. Most of them date from around the ninth century, but U48 and U15 go back to the fifth or sixth centuries.

Not much can be said about U48, except that it is a palimpsest in which the superimposed text is a series of sermons by Gregory of Nazianzus, and that it was once in Calabria where 'influences of the Greek Orthodox Church were strong in the Middle Ages' (Heath, 1965, 4). Slightly more is known concerning the history of U15. After becoming dilapidated, it was taken apart while at Athos and is now scattered among six European libraries. It is arranged in Euthalian sense-lines and contains a colophon stating that 'The book was collated with the copy which is in Caesarea in the library of the holy Pamphilus and which was written by [his] hand' (Murphy, 1959, 228-9). Another one of the manuscripts, U25, is a palimpsest with a Euthalian text superimposed upon it.

The colophon provides a reasonably positive link between U15, or one of its ancestors, and Caesarea. According to Zuntz (1945, 88), 'the text edited by 'Euthalius' was a Caesarean text, more precisely, that of Pamphilus.' Even if Caesarea was the distribution centre for Euthalian manuscripts, the fact that they occur in Latin, Syriac, Armenian, and Georgian translations (Murphy, 1959, 229) should be considered before jumping to the conclusion that Euthalian material necessarily implies Caesarean provenance.

Robinson (1895, 43-7) surveys evidence indicating that the Greek edition of Euthalius could, at various times, have been found in Egypt, Syria, Asia Minor, and even Sardinia, but agrees that it was apparently known in fifth century Palestine (36). The contention that Euthalian manuscripts written in Greek could come from Syria is supported by the fact that the Harklean revision of the Philoxenian version is Euthalian. Given that the Greek basis of the Philoxenian version was also Euthalian, it follows that there was at least one Euthalian manuscript of the Greek New Testament in the heart of Syria when Polycarp of Mabbug made his translation in 508 CE.

The colophon and Euthalian arrangement suggests a connection with Palestine or Syria that may be shared by the whole group. The Moslem conquests of these areas would seem to rule this out, given that most of the manuscripts in question are dated after the seventh century. However, Christians were allowed to maintain many of their activities under Moslem rule (Schick, 1998, 86), so New Testament manuscript copying in Palestine and Syria could have continued into the ninth century.

Three of the manuscripts have commentaries. In view of their dates, this is not unusual. The commentary in U75 and U150 is by John of Damascus. C. R. Gregory thought that the commentary in U18 was by Theodoret; however, the first two sections in Hebrews match with Oecumenius, while the third has some different wording. (I am indebted to Dr Klaus Wachtel of the Institute for New Testament Textual Research in MŸnster for this information on the commentaries.)

John of Damascus (c. 655 - c. 750) lived in Syria until about 725, when he moved to Jerusalem. It is not as simple to locate the author of the commentary in U18. The entry for Oecumenius in *The Oxford Dictionary of the Christian Church* (1997, 1176) says that the commentary on the Pauline epistles ascribed to Oecumenius could have been written by the tenth century Oecumenius who was Bishop of Tricca in Thessaly, but the ninth century date of U18 would seem to rule this Oecumenius out of contention. The dictionary article goes on to say that the same commentary may have been written in part by the sixth century Oecumenius who is known for writing a commentary on the Apocalypse: 'Fragments from [the] Comm. on the Pauline epistles in the catenae,

ascribed to Oecumenius of Tricca, may, however, belong to the author of the Comm. on Rev.' The information given by Dr Wachtel suggests to me that the commentary in U18 might be a catena containing quotations from Oecumenius and Theodoret. If so, the dictionary article's point about catenae can be taken as support for the notion that the sixth century Oecumenius wrote at least a part of the U18 commentary.

Given that the commentary in U18 should be associated with this Oecumenius, a location for him is still required. The dictionary article says, 'Little is known of his life, but he appears to have been a contemporary of Severus of Antioch.' If the sixth century Oecumenius was also from Antioch then the commentaries of U18, U75, and U150 can be linked with Syria by implication of their authors' common association with that region. The same implied provenance remains if the U18 commentary was written by Theodoret since he, too, lived in Syria.

A number of the manuscripts share an association with Greek Orthodox monasteries. Heath draws a link between U48 and the monastic tradition. Both U44 and U150 still reside in monasteries, while U15 is known to have been at Athos. However, this characteristic does not say much about the group in question because it would be hard to find an uncial Greek New Testament manuscript that has not spent time in an Orthodox monastery.

The implications of these circumstantial investigations are tenuous, to say the least. A Euthalian text does not guarantee a connection with Caesarea. Neither do the commentaries provide an irrefutable link with Syria. Perhaps a different approach can provide the answers we seek. One way forward is to associate major Greek-speaking Christian population centres with the centres implied by clustering in the spelling maps.

Major Christian population centres would, in general, have been manuscript copying centres as well. If a centre had a distinctive text and way of spelling, then we can expect its manuscripts to be distinguished by the kind of analysis that produces the classical scaling maps of this study. Adolf Harnack's *Mission and expansion of Christianity in the first three centuries* assists with the identification of population centres that

might have given rise to these distinctive manuscripts.

Rather than attempting specific population estimates, Harnack (1908, 327-9) listed regions according to four categories. The first includes districts where 'Christianity numbered nearly one half of the population and represented the most widely spread or even standard religion, by the opening of the fourth century.' Among these districts were virtually all of Asia Minor, the region of Thrace opposite Bithynia, and Armenia. The second category includes regions where 'Christianity formed a very important section of the population, influencing the leading classes and the general civilization of the people, and being capable of holding its own with other religions.' Among Greek-speaking cities included under this heading are Syrian Antioch and Alexandria. Both cities stand out as plausible candidates for the major centres being sought.

The importance of Constantinople demands that it be added to the list. This city may even have inherited aspects of the text and spelling of Asia Minor's most ancient New Testament manuscripts, assuming that there was a distinctive regional text in early times. Another place that should not be forgotten is Caesarea in Palestine. All indications are that this was an authoritative centre during a crucial phase of New Testament textual history. Its episcopal library contained many of Origen's works. Pamphilus laboured there, and a number of colophons indicate that its biblical manuscripts were valued as exemplars. Even Constantine turned to Caesarea to supply fifty copies of the Bible for churches in his new capital city:

About A.D. 331, when Constantine wished to secure copies of the Scriptures for the new churches which he proposed to build in Constantinople, he wrote to Eusebius requesting him to arrange without delay for the production of 'fifty copies of the sacred Scriptures É to be written on fine parchment in a legible manner, and in a convenient portable form, by professional scribes (kalligraphoi) thoroughly accomplished in their art' (Metzger, 1992, 7).

Antioch, Alexandria, Caesarea, and Constantinople are, then, likely candidates for major production centres that could have given rise to Greek New Testament manuscripts with distinctive spelling and textual

characteristics. The spelling maps show that witnesses tend to congregate around three major centres, and this tripartite structure is corroborated by the textual maps. We must now connect the three spelling groups and four centres. According to the Alands (1989, 65), the exegetical school of Antioch was a catalyst for the spread of one kind of text to episcopal sees from Antioch to Constantinople. If so, the first spelling variety should be identified with Constantinople and Antioch. The second spelling group can be connected to Alexandria by virtue of its clearly Egyptian members. This would leave Caesarea to be identified with the third spelling group.

In the introduction to *The four Gospels*, B. H. Streeter (1925, xii) stated that his 'most original conclusion, and perhaps the most important, is the identification of the text found in the Koridethi MS. Q, and its allies, with the text in use at Caesarea about 230 A.D.' According to Metzger (1992, 214-5),

'Subsequent investigations by Lake, Blake, and New showed that the Caesarean text probably originated in Egypt and was brought by Origen to Caesarea, from where it was carried to Jerusalem (a number of Caesarean witnesses contain the so-called Jerusalem colophon^É), to the Armenians (who had a colony in Jerusalem at a very early date), and thence to the Georgians (codex Koridethi belongs to Georgia).

Later, Metzger (1992, 290) writes that 'recent research has tended to disintegrate still further whatever unity Streeter and Lake originally attributed to it.' The Alands (1989, 66) admit the theoretical possibility of a Caesarean text but say 'the widely acclaimed Caesarean text of the New Testament, we must insist, is thus far purely hypothetical.' In their opinion, the dedicatory letter to Damasus in Jerome's edition of the Gospels only supports two kinds of text, not three. Neither, they say, has research established that Origen and Eusebius quoted from a Caesarean New Testament text. These are valid arguments, but the new evidence provided by the spelling and textual maps of this study makes it clear that a third textual variety does exist for Hebrews. Whether it should be identified with Caesarea is not so clear.

Neither the circumstantial nor the population centres approach succeeds

in giving an unequivocal identification to the three textual and spelling groups. The circumstantial approach results in these identifications:

Group 1: Probably Constantinople, but may be Antioch

Group 2: Probably Egypt, but may be Caesarea

Group 3: Possibly Caesarea or Syria

The population centres approach gives:

Group 1: Constantinople and Antioch

Group 2: Alexandria

Group 3: Caesarea

The results of both approaches are so ambiguous that it may be a waste of time to attempt a synthesis. Nevertheless, I provide the following identifications of spelling groups with geographical domains that I regard as somewhat less problematic than other possibilities. The same identifications serve for the three textual groups as well.

Group 1: Constantinople (possibly encompassing Antioch)

Group 2: Alexandria (possibly encompassing Caesarea)

Group 3: Caesarea (possibly encompassing Antioch)

The identification problem is particularly acute for the third group. Perhaps there is another explanation for the common spelling characteristics of its manuscripts. If they were all copied in monasteries that had a uniform spelling code, for example, then their spelling unity could be attributed to shared monastic origins. If their unity is related to locality then this spelling group may be identified with Caesarea or even Antioch. A serious difficulty that goes against both these places is the generally late dates of the witnesses. As mentioned before, Christian manuscript production may have continued in Palestine and Syria after the Moslem conquests. If this turns out not to have been the case, then a different locality must be sought.

A few final observations concerning spelling resemblance are in order. Assuming that spelling does correspond to locality, then P13, P46, U1, U2, U3, U6, and U16 come from the same region. If my identification is

correct, then this region encompasses Egypt and, possibly, Caesarea. Following this line, the views that U6 was copied in the West, and that U2 was copied in Constantinople would be wrong. However spelling may not correspond to locality, and uniform spelling practice may be due to another cause. If a particular mode of spelling were adhered to in diverse locations, then uniform spelling would not imply like provenance. Nevertheless, it would still point to a common bond possessed by the manuscripts with similar spellings.

As noted before, the supplementary portion of Hebrews in Codex Sinaiticus has a different textual character to the remainder. In the spelling perspective, both U1 and U1s lie on a trajectory between U2 and U6. (The second map of the U1s spelling map-pair shows that the apparent disagreement with this situation displayed by its first map can be attributed to parallax.) This is not to say that the spelling practices of the respective scribes (Tischendorf's 'A' and 'D') are identical. On the contrary, Milne and Skeat (1938, 51-4) commend the use of spelling as a criterion to distinguish between them. Nevertheless, it can be said that their spellings do not differ to the same degree as their texts. This, in turn, implies that the two scribes shared the circumstances that determine spelling practice, but employed textually different exemplars for their respective parts of the Codex.

At this point it is appropriate to mention the manuscripts discovered at Saint Catherine's monastery in 1975. I look forward to the day when they are published in full. Until that day, it will remain impossible to carry out a comparison of their spellings and texts. It would be most interesting to do so, especially since there is a good chance that the manuscripts originated in the same region. Studying them might provide evidence to support the postulated link between spelling and locality. Since the maps show that U278 is textually akin to U25 and U150, such a study might even throw light on the vexed question of the third spelling group's regional identity.

In Codex Sinaiticus, the scribe responsible for the Hebrews supplement is thought to have been a contemporary of the principal scribe (Milne and Skeat, 1938, 62). I do not know whether the same is true of U75: another manuscript in which a sizable part of Hebrews has been copied

by a second scribe. In this codex, the text of the supplement is akin to that of U25 and U150 (i.e., group 3) but the spelling resembles that of M2815 (i.e., group 1). In the rest of Hebrews, the situation is reversed. This inversion is difficult to understand in terms of a localised spelling theory. Part of the inconsistency may be explained on the assumption that the respective scribes were not contemporaries. In this case, the group 1 spelling I have associated with Constantinople could have been used because the manuscript was located in a place that used this spelling code when the supplement was copied. But then we would be left with the unlikely although not impossible scenario of a scribe using the spelling of Constantinople while copying a non-Byzantine text (cf. U243).

The last few spelling maps pertain to specific transformations rather than all spelling transformations collectively. These maps have been generated for the twelve 'complete' witnesses alone. Separate map-pairs could have been made for each witness with a sufficient number of units. Instead of pursuing this aim, I have settled for a less comprehensive approach that merely aims to see whether the combined analysis of all spelling transformations produces similar results to separate analyses of individual transformations. My reason for doing so stems from a statement by Kenneth E. Panten (1995), who conducted a study of words for which the spellings of Codex Bezae and NA27 differ. He reached the following conclusion after searching for associations by date and geographical location using data from Greek papyri, ostraca, and tablets:

Unfortunately the exercise proved fruitless, mainly because of the many citations that are not dated, or, to a far lesser degree, not located geographically. Therefore most of the citations not of Greece and Egypt do not appear on the table giving a very biased result. Furthermore the majority of citations, which come from Egypt, show that both forms of spelling [i.e., the spellings of NA27 and Codex Bezae] were used there. The few citations that come from Greece demonstrate a propensity to favour the spelling of the Bezan words, but are insufficient in number to draw a firm conclusion (Panten, 1995, 439).

Part of the reason for the inconclusive result may be that each kind of spelling variation was considered individually. It is possible that a

multivariate analysis that considers every kind of variation has a better chance of success.

Returning to the spelling maps, both directions of change are lumped together for all but one of the transformations. The E to AI and AI to E spelling transformations are treated separately. Their maps show that each direction of change contributes distinctive information to the picture obtained for the bidirectional transformation. In the same way, the picture obtained by combining all of the bidirectional transformations is not necessarily discernible in the constituent transformations. For this reason, any manuscript characterisation that is restricted to a single spelling transformation is prone to failure.

The EI-I and U-V changes account for the majority of transformations considered in the combined spelling analysis. It is no coincidence that maps based on these two changes are more comparable with the combined spelling maps than maps of other specific transformations. The U-V change tends to separate manuscripts in the second spelling group from the others, while the EI-I change tends to isolate the first spelling group. The map devoted to movable *nu* spelling variation is also notable because it differentiates U56 and U142 from the rest. This is interesting because movable *nu* variations almost never enter into the analysis that produces the textual variation maps. Despite this, the textual maps tend to isolate U56 and U142 as well. That is, the textual and movable *nu* perspectives independently show that U56 and U142 share a distinctive character.

Other maps

The 'other maps' appendix covers word division, *kaiv* compendium, line division, and punctuation practices. Two of the map-pairs are restricted to the verses for which U15 is extant, while the rest are devoted to the twelve 'complete' witnesses.

The word-division map-pair relates to places where words are divided in a different manner to the UBS4 text. In the main, these differences are caused by a scribe separating the prefix from a word by inserting an apostrophe (e.g., FIL' ADELFA for FILADELFA). The affiliations shown

with respect to word-division are not very informative as they are based on a small sample of units.

There are enough units to be confident of affiliations shown in the *kaiv* compendium map-pair. Witnesses that are tightly clustered, such as P46, U2, U6, U150, TR, and UBS4, have in common a tendency not to use the compendium in the same places as other witnesses. The lack of close association among the other witnesses (besides U56 and U142) shows that scribes tended to use compendia as they saw fit rather than according to their exemplars or an established rule.

The first line-division map-pair groups witnesses that divide text between lines at the same places. Grouping in these maps may be due to an intentional effort to reproduce the layout of one manuscript in another. Such an explanation could be appropriate for the associations of U56 with U142, and U18 with U151. The same associations occur in the textual maps, indicating that the respective pairs of manuscripts are closely related. The spelling maps show that U56 and U142 have similar spellings as well, but U18 and U151 are spelt differently. The case of U18 and U151 supports the view that spelling was particularly liable to change during copying.

The association between the UBS4 text and the *Textus Receptus* (TR) is not genuine, but occurred because I placed line-divisions between verses in their electronic texts. The affiliation of U25 and M2815 is surprising as these two witnesses differ in text and spelling. It may be that line-divisions randomly coincide more often in manuscripts with similar line lengths than in those with disparate line lengths. If so, any attempts to associate witnesses on the basis of line division are suspect.

A line-division map-pair is also provided for U15. This manuscript is arranged in sense-lines, and it is notable that its closest neighbour in the maps is U6, another manuscript with colometrical arrangement. The next closest neighbour is U1, which is not arranged in sense-lines but does have quite short line lengths Ñ a characteristic shared with U6 and U15. Besides the addition of two extra witnesses, the features of this map-pair are comparable to those of the other line-division map-pair.

The first punctuation map-pair is based on exact punctuation correspondence. That is, two witnesses are required to have the same punctuation mark in the same place to register an agreement. This is quite a stringent requirement given the variable usage of punctuation marks in the Greek manuscript tradition (Robertson, 1923, 241-5). Once again, U18 and U151 resemble each other, as do U56 and U142. This time, however, U25 is in the same area as U56 and U142, which implies that these three manuscripts share common ground in punctuation.

Such a result is unexpected because the textual and spelling perspectives indicate that U25 is unlike U56 and U142. The inconsistency can, however, be understood in terms of the application of universal rules. This explanation is particularly apt in the context of punctuation. The same punctuation marks were inserted at the same places because scribes divided their texts according to sense and because they had a common understanding of the functions of various punctuation marks, regardless of where they lived.

There is a tight cluster of witnesses comprised of P46, U6, UBS4, and TR. Their high degree of conformity is probably the result of double zeros in the dissimilarity matrix from which this map-pair derives. In other words, the shared characteristic of these four witnesses is a lack of agreement with the punctuation of other witnesses. This is not difficult to understand considering that U6 is devoid of punctuation marks, and that P46 is almost so. The electronic transcription of the *Textus Receptus* used here also lacks punctuation marks, but the electronic UBS4 text has the exact punctuation of the printed edition. This leads to the conclusion that the UBS4 text is not punctuated according to the conventions of the uncial Greek manuscripts.

The next map-pair is based on levelled punctuation. In generating the relevant dissimilarity matrix, all punctuation marks were levelled to a single mark. Therefore, these maps reveal correspondence in the placement of punctuation. There is agreement with the preceding map-pair concerning the affiliations of U18 with U151, U56 with U142, and the shared disparity of P46, U6, and TR. A number of contrasts stand out as well.

The association of U25 is no longer with U56 and U142, but has shifted towards M2815. This can be interpreted to mean that U25 has a higher than usual agreement with U56 and U142 as regards punctuation marks, and a higher than usual agreement with M2815 for punctuation placement. The line-division maps manifest an affiliation between U25 and M2815 as well. In the related discussion, I suggested that the resemblance might be due to random agreements caused by similar line lengths. However, a shared placement of punctuation cannot be attributed to the same cause, implying that a relationship between these two manuscripts does exist at the level of formatting.

This apparent relationship between U25 and M2815 is perplexing as the two manuscripts have little in common. One is uncial and the other minuscule, their texts and spellings are disparate, and they are separated by a span of three centuries. Whereas shared punctuation might be due to universal punctuation practices, the same cannot be said of line division. Heredity could account for agreement in punctuation and line division, but is ruled out by the differing texts. Given that agreement in punctuation can be attributed to universal punctuation practices and agreement in punctuation might be explained by similar average line lengths, it is possible that the two kinds of agreement occur in conjunction by coincidence. This explanation leaves much to be desired; perhaps a future investigation of the apparent link between U25 and M2815 will provide a better one.

In the maps that compare specific punctuation marks, UBS4 was aligned with the manuscripts that share disparity of punctuation. Once the punctuation marks are levelled, the relative position of UBS4 shifts to a location near U2. That is, UBS4 and U2 tend to divide the text in corresponding places, even if they don't use the same punctuation marks.

The last map-pair of this section is based on the verses for which U15 is extant. The corresponding dissimilarity matrix was produced by levelling punctuation and line-division characters to a single character. This was done to allow colometrically arranged manuscripts such as U6 and U15 to be compared with manuscripts that use punctuation to mark sense-pauses. As far as sense is concerned, the resultant maps show that U6 is divided in a similar manner to witnesses such as U2, U25, U44, M2815,

and UBS4. The same pattern of affiliation is not found in the textual and spelling perspectives. Once again, this incongruous behaviour can be attributed to the operation of a universal set of rules: pauses are inserted according to sense, so scribes and editors in diverse circumstances will arrive at the same divisions.

The ubiquitous associations of U18 with U151, and U56 with U142 occur in this map-pair as well. Witnesses such as P46, U1, and TR congregate together, probably because they share an inclination to disparate punctuation and line division practices. Part of the structure seen within these maps may be due to the general increase of punctuation usage with time. The same goes for the maps devoted to punctuation alone, where position along the first axis appears to show some correlation with manuscript date.

To conclude observations concerning this map-pair, U15, U25, and U150 appear to lie in the same general area, indicating that they have a shared practice when it comes to sense-division. These manuscripts are also part of the third spelling group that was discussed before. They are quite close to each other in the textual maps, although the text of U15 is more akin to manuscripts like U2. One is a Euthalian manuscript (i.e., U15) and another has a Euthalian text superimposed (i.e., U25). Whatever the reason for their affiliation, the fact that it recurs in the textual, spelling, and sense-division perspectives points to a deep-seated relationship existing between them.

This discussion has raised some points that relate to ways of explaining agreement between witnesses. Patterns of agreement seen in textual and spelling maps are often comparable with each other. As a general rule, they do not resemble the patterns of agreement seen in maps devoted to peripheral phenomena such as line-divisions and punctuation marks (i.e., the 'other' maps). The working theory outlined before is capable of accounting for patterns of agreement in textual and spelling variation but can fail when it comes to the peripheral phenomena.

My theory attributes textual affiliation to the inheritance of readings that go back to primitive archetypes. Spelling affiliation is put down to common locality. Apparently, shared spelling results from scribal

application of local rules. Affiliation of peripheral features in otherwise unrelated witnesses can be explained in a similar way: namely, the application of rules. The scope of these rules may be local, in which case the patterns of affiliation between peripheral features will correspond to those seen for spelling variation. Their scope may also be non-local. There are many possibilities in this regard, including contemporary or universal domains of operation.

Another cause of resemblance among otherwise unrelated witnesses is random agreement, whereby scribes arrive at the same features by coincidence. In my opinion, coincidental agreement is more likely to apply to features that a scribe would regard as unimportant or without authority. This is because features for which there was definite authority or to which definite rules applied would have been more likely to be copied according to the relevant authority or rule rather than the scribe's whim. Coincidental agreement also covers situations where a scribe would guess the form of a feature to avoid the trouble of finding the authoritative form.

Correctors

Observations concerning the texts and spellings of correctors whose maps are based on more than fifteen units are tabulated in fig. 1. Where possible, corrector texts and spellings are classified according to the three groups already discussed. For comparison, classifications are also given for the first hands of the relevant manuscripts. The table aims to bring out the dynamic aspects of textual development revealed by examining stages of correction. Consequently, it describes witness dispositions by way of codes that refer to relative movement as well as location. A key explaining the codes found in the 'text', 'spelling', and 'comments' columns is appended.

The 'X-Y' notation is used for texts or spellings that might belong to either of two groups (e.g., '1-3'). It is also used to define a point between manuscript locations. In the latter case, it can be understood as shorthand for 'what manuscripts X and Y have in common' (e.g., 'U25-U150'). A question mark '?' in the text or spelling columns means that the affiliation of a witness relative to the three reference groups is not certain because:

- (1) the distance from the witness to the groups is too great for a clear link to be established (e.g., text of U6-3);
- (2) the witness is midway between all three groups (e.g., text of U4-x); or
- (3) an unusual witness distribution makes the groups indistinct (e.g., text of P46-2).

The comments section provides the number of units for those map-pairs which I regard as having unusual witness distributions. This is because a small sample size can be the cause of an apparent change in group structure. If the witness distributions of a corrector map-pair and its first hand map-pair are significantly different then an asterisk is placed adjacent to the corrector's group classification. A group classification may still be possible despite a distribution change (e.g., text of U142-1). Affiliation cannot be determined in cases where a changed distribution has made the reference groups indistinct because classification requires the groups to be well defined entities.

A number of codes are used to describe the motion of a corrector relative to its first hand and the other witnesses plotted in the maps. Correctors that do not show much movement relative to their first hands are designated 'stationary' ('S'). A corrector is classified as stationary if it moves less than fifteen millimetres from its first hand in both maps of the relevant pair. This simple criterion is quite arbitrary, but serves well enough to distinguish correctors with a dynamic tendency from more static ones. Correctors that move a significant distance from their first hands are termed either 'transitional' ('T') or 'divergent' ('D'). The distinction between these last two classifications is to do with their apparent destinations. A transitional corrector stands on or near a trajectory linking its first hand with a region occupied by other witnesses. A divergent corrector stands on a trajectory that heads towards an unoccupied area of the maps.

The arrow symbol ('->') stands for 'converges towards', and is used when a corrector appears to be heading towards a particular witness or cluster. In some cases, the arrow is used to indicate a convergent tendency even when the corrector has been classified as stationary according to the fifteen millimetre distance criterion. This apparent contradiction in terms occurs because the criterion does not always distinguish between true

motion caused by intentional revision and false motion caused by random fluctuations in position. The same kind of problem is encountered whenever a threshold level is used to discriminate between a meaningful signal and noise.

Now that the codes have been explained, the observations summarised in fig. 1 can be analysed. As might be expected, the texts and spellings of scribes who have corrected their own work (designated by a '-0' suffix) are generally stationary, remaining in the same neighbourhood as the originals. It makes sense that auto-corrections should not diverge from their prior states because scribes would not normally correct their own text using a different exemplar, or change their spelling habits from one day to the next. In the case of U6-0, the text appears to be mobile rather than stationary. This movement can be attributed to a random fluctuation exacerbated by the small sample size of only sixteen units. The change of spelling in U75-0 is not so easily dismissed. Here, the tendency is towards the centre of the relevant spelling group, suggesting that the scribe may have corrected his work to the prevailing standard. Alternatively, my attribution of these corrections to the original scribe could be wrong.

The 'x' category used to capture alterations that cannot be attributed to particular correctors of a manuscript often exhibits a mixture of the characteristics of the identified correctors. The unattributed textual alterations that comprise U4-x display aspects of the U4-1 text (a divergent tendency) and the U4-2 text (a tendency towards the group 1 text). Given that the U4-x category is a mixture of U4-1 and U4-2 alterations, the fact that the texts of U4-1 and U4-2 are classified differently helps to explain why the textual classification of U4-x is indeterminate. Similar patterns of behaviour can be detected for U6-x and U142-x as well. After examining the maps it may even be possible to say that a majority of the unattributed corrections belong to one of the identified correctors. For example, the tendency of U6-x towards the group 1 text suggests that a significant proportion of these unidentified alterations are due to U6-2, who displays the same tendency.

Turning to the identified correctors (i.e., excluding auto-correctors and unidentified correctors), the texts and spellings are distributed between

the stationary, transitional, and divergent categories as follows:

Text

Stationary: P13-1, P46-1, U1-2, U3-1, U3-2, U3-3, U20-2, U44-1, U122-1, U142-1, U150-1

Transitional: P46-2, U1-3, U1s-3, U4-2, U6-2, U15-1, U44-2

Divergent: U4-1, U6-1, U6-3, U142-3

Spelling

Stationary: P46-1, U1-3, U1s-3, U4-1, U4-2, U6-1, U15-1, U20-2

Transitional: U3-2, U3-3

Divergent: U1-2, U6-2, U6-3

A number of interesting patterns emerge. In general, the first corrector tends to use an exemplar of the same textual group as the manuscript being corrected. As may be seen, P13-1, P46-1, U1-2, U3-1, U44-1, U122-1, U142-1, and U150-1 are all stationary. (The first corrector of Sinaiticus is designated U1-2 in this thesis because I decided originally to designate the scribe responsible for the supplement as U1-1. Later, I changed this designation to U1s but did not alter the corrector labels.) While the texts of U4-1, U6-1, and U15-1 are mobile, their textual affiliations do not change. According to Streeter (1925, 35),

In the scriptoria of the great libraries it was customary in antiquity for a corrector, *diorqwthv*", to go over a MS., sometimes with the original from which it was copied, more often, apparently, with another copy.

Any of the first correctors listed here could have been a *diorqwthv*". (This may not apply to U3-1 for the reason given in the U3 transcription notes introduction.) Each stationary case speaks of a *diorqwthv*" using the same exemplar as the copyist. Each of the mobile cases implies that a different exemplar was used, but one belonging to the same text group nonetheless. The evidence presented here suggests that a typical *diorqwthv*" used the same text as the copyist more often than not.

Other correctors copied in this conservative manner as well. The text of U20-2 is stationary, which is not surprising because this scribe did nothing but copy the original text onto repaired folios of the codex.

Apparently, the original spelling of U20 was conserved too. In Codex Vaticanus, U3-3 adhered closely to the first hand's text, only rarely making the kind of alteration that attracted the rebuke found in the column at Heb 1.3: *ajmaqevstate kai; kakev, a[fes to;n palaiovn. mh; metapoivei. Bad and ignorant scribe! Leave the old reading alone. Don't change it.* The corrector designated U3-2 also stayed close to the first hand's text.

Milne and Skeat (1938, 41) attribute many of the alterations in Codex Sinaiticus to the manuscript's original scribes:

Since we have already concluded from the evidence of the supplementary apparatus that both A and D, in addition to copying the text, were engaged in the further equipment of the manuscript, we may expect to find both among the correctors. Further examination has not only confirmed this surmise, but has enabled us to apportion the entire body of 'A' and 'B' corrections to these two scribes, although to distinguish between them is not always possible.

Tischendorf assigns all of the corrections in Hebrews to the 'A' and 'C' groups of correctors. In my nomenclature, U1-2 corresponds to Tischendorf's 'A' correctors, and U1-3 to his 'C' correctors. As Milne and Skeat apportion all of the 'A' corrections to scribes A and D, it follows that U1-2 consists entirely of corrections by these two scribes. (Unfortunately, the conventional terminology makes it easy to confuse scribe A with the group 'A' correctors.) Moreover, all of Hebrews was written by scribe A, excepting the supplementary folio written by scribe D. This means that U1-2 corrections in the parts written by scribe A are either auto-corrections or alterations by scribe D. It seems most unlikely that Tischendorf would have attributed so many alterations to a different hand if they were actually by the first hand. The alternative is far more attractive: scribe D, who is designated U1s in this study, is responsible for the U1-2 corrections. This conclusion is borne out by the fact that Tischendorf did not assign any of the alterations in the supplementary folio to the 'A' group correctors. It is not a new idea; according to Lake (1911, xxiv), scribe D was the *diorqwthv* of Sinaiticus and should be identified with at least one of the 'A' group correctors. Tischendorf, also, ascribed some of the 'A' group corrections to scribe D (Lake, 1911, xxi).

If the maps are of any value they should indicate that U1-2 and U1s are one and the same scribe. The textual maps for U1-2 show it to be on a trajectory from U1 (which we now identify as scribe A of Sinaiticus) to the vicinity of P46. The maps of U1s show that this scribe's text is located between the texts of U2 and P46. As noted before, the texts of U1 and U2 are almost identical in the parts of Hebrews copied by scribe A, so U2 can be taken as representative of U1. It follows that the respective maps have succeeded in placing U1-2 and U1s in corresponding positions. This is a remarkable achievement, more so when it is considered that the maps are independent of each other, being based on complementary portions of the text.

While on the subject of U1s, Tischendorf thought that scribe D of Sinaiticus should be identified with scribe B of Vaticanus, who copied the New Testament in that codex (Milne and Skeat, 1938, 89). This view was rejected by Lake (1911, xii) who wrote that there is 'good evidence for thinking that the two great codices come from the same scriptorium, in spite of the fact that Tischendorf was wrong in thinking that they were written by the same scribe.' Milne and Skeat (1938, 90) agree that Sinaiticus D is not Vaticanus B, but they are impressed by similarities between Sinaiticus D and Vaticanus A, both of whom corrected their respective New Testaments. As noted in the U3 transcription notes introduction, I am not convinced U3-1 precedes U3-2. For this reason, I cannot say whether Vaticanus A should be identified with U3-1 or U3-2. Fortunately, this is not a major hindrance because the textual maps show that U1s, U3-1 and U3-2 all lie in approximately the same position relative to near neighbours such as U3 and U2. That is, the textual maps do not contradict the assertion that Sinaiticus D is one of the early correctors of Vaticanus.

Moving on to transitional correctors, a general tendency towards group 1 or group 3 texts is evident. Only U1-3, U1s-3 and, perhaps, U6-3 move towards the group 3 text. A stationary corrector, U3-1, shows a tendency towards U25, which is also a group 3 text. The rest of the transitional correctors, being P46-2, U4-2, U6-2, U15-1, and U44-2, converge on the group 1 text. No corrector displaying a significant textual deviation from its first hand moves towards the group 2 text. Since correctors always

post-date their first hands, the table reveals a consistent temporal trend away from the group 2 text predominately towards the group 1 text. To use more conventional terminology, the text of Hebrews was revised away from the Alexandrian text and towards the Byzantine text as time elapsed.

This approach to determining textual trends is superior to one which focusses on the relative number of manuscripts affiliated with the respective text groups as time progresses. The earliest manuscripts generally come from Egypt where they have been preserved by the dry climate. As a consequence, manuscripts which have a group 2 text tend to be over-represented in the latter approach. By contrast, the directions of textual development revealed by concentrating on corrected manuscripts alone are less prone to influence by factors relating to manuscript survival. Nevertheless, the trends so revealed only pertain to the specific places and times of correctional activity for the relevant manuscripts.

Fig. 2 gives my appraisal of the textual tendency of each identified corrector, arranged according to date. First correctors have been excluded because they are usually contemporary with the first hand, and are unlikely to reveal temporal trends for that reason. Corrector dates are converted from century-style dates. Most of them are taken from the *Synopsis of Sigla for Correctors in Manuscripts* given in the Alands' *Text of the New Testament* (1989, 108). The date of P46-2 is from Zuntz (1953, 254). In the case of U20-2, U44-2, and U142-3, I have assigned indeterminate dates later than their respective first hands, whose dates are taken from appendix 1 of NA27 (1993, 689-698).

Any attempt to draw conclusions from this quite limited survey is hazardous because the inclusion of more correctors could change the situation markedly. Putting this reservation aside for the moment, there appears to be an episode of correction towards the group 3 text that is preceded and followed by episodes of correction towards the group 1 text. Both U3-2 and U3-3 display no particular trend away from the group 2 text. All of the later correctors that move towards group 1 were working on texts already belonging to that group. Consequently, the final episode of correction towards the group 1 text should not be regarded as

a transitional trend. This would make the overall impression one of correction towards group 1 followed by an episode of correction towards group 3. That is, there would appear to have been two phases of standardisation: the earlier towards the Byzantine text, and the latter towards what might be called the Caesarean text. This is consistent with a text that was made popular by the Caesarean scriptorium becoming influential in other Greek-speaking parts of the Empire around the middle of the first millennium.

The group 1 text lies directly beyond the group 3 text in a number of the transitions. Hence, what appears to be convergence towards group 3 might actually represent incomplete revision towards group 1. Streeter (1925, 40-41) gives an entertaining account of why this might have happened:

Let us suppose that the text of the Gospels in a particular city or monastery was of the B type, and that the Bishop or Archimandrite, on a visit to Constantinople, wished to correct it to the standard text. He would bring his own copy with him and tell off one of his attendant priests or monks to collate it with the model. Two-thirds of the 4000 or more differences which the microscopic eye of a Tischendorf, trained by a lifetime of such comparison, would detect, this man would never notice. Of the rest, at least half would seem to him too unimportant to record, since they make no real difference to the sense. If the corrector were more than usually careful, and had plenty of leisure for the work, he might make 500 corrections; if careless or pressed for time, perhaps only 50. The copy thus corrected would be taken back; and from it other local copies would be made, *embodying these corrections in the text*. What then would be the character of the resultant text? It would be a *mixed text*, some of its readings being Alexandrian, others Byzantine.

This is relevant to the present discussion even though we are concerned with Hebrews and not the Gospels. (Streeter's 'B type' refers to the text of Codex Vaticanus and is equivalent to my group 2 text.) A case might be made that the entire third group is nothing more than a halfway house between the Alexandrian and Byzantine texts. There is, however, reason to believe otherwise. If group 3 witnesses are merely the product of partial revision, they should be uniformly distributed between the

respective Alexandrian and Byzantine poles. The fact that they appear to concentrate in one area indicates that the third group is a distinct entity.

The correctors of Codex Sinaiticus designated U1-3 and U1s-3 both represent Tischendorf's 'C' group of correctors, but are treated separately because my transcriptions divide Hebrews into the parts copied by U1 (i.e., Sinaiticus A) and U1s (i.e., Sinaiticus D). As should be expected, the textual maps are consistent with U1-3 and U1s-3 being one and the same corrector. Both texts converge towards group 3, and both end their journeys close to, if not within, this text group. Kirsopp Lake (1911, xvii-xviii) has the following to say about the 'C' corrector group:

Taken together they have done far more work on the MS. than any others, and afford extremely important material for textual criticism; as was shown [before] they represent a Caesarean scriptorium, for one of them who does not, however, seem to have touched the New Testament states that he corrected part of the text of the Old Testament according to the copy of the Hexapla made by Pamphilus during his imprisonment, and preserved in the library at Caesarea

On the whole the C hands so closely resemble each other, and can with such little confidence be much separated in date, that there is considerable force in the suggestion that they all come from the scriptorium at Caesarea, and represent a thoroughgoing attempt to accommodate the Codex Sinaiticus to a model which in the fifth and sixth century was more fashionable than the original text.

Such a magnificent codex as Sinaiticus would certainly deserve a thorough rather than piecemeal revision. It may well have served as a reference work (Streeter, 1925, 43), in which case the correctors would have been especially careful to make its text fully conform to their standard copy. Assuming that the 'C' correctors did a thorough revision, it follows that U1-3 and U1s-3 accurately reflect the text they used as an exemplar. Their association with Caesarea and proximity to the third textual group combine to link the group 3 text with a text current in Caesarea when the 'C' group correctors did their work. This was 'probably not earlier than the fifth nor later than the seventh century' (Lake, 1911, xvii).

We should expect the 'C' correctors to converge on the group 3 spelling as well. Contrary to this expectation, the spelling maps show that both U1-3 and U1s-3 are of group 2 and stationary, with no inclination towards group 3 whatsoever. Why would the 'C' correctors employ one kind of text and another kind of spelling? Milne and Skeat (1938, 46-50) identify four 'C' group correctors who worked on the New Testament. Of these, one made corrections in the whole New Testament, one worked on the Gospels alone, and the other two restricted themselves to the Apocalypse and epistle of Barnabas. This implies that only one worked on Hebrews: the one designated C^a by Tischendorf. Consequently, the question just posed refers to an individual scribe.

Perhaps this scribe was an Egyptian who had moved to Caesarea. Then again, a Caesarean manuscript might have been taken to Egypt where it served as a model for corrections to Sinaiticus by native scribes. These are not the only possibilities. Judging by Tischendorf's notes concerning corrections in Hebrews (1862, xxxx), there are not enough spelling changes by C^a to materially affect its position relative to the other witnesses, particularly in the supplementary folio. Instead, its spelling position is principally determined by uncorrected words in the verses of Codex Sinaiticus that scribe C^a has altered. That is, U1-3 and U1s-3 are stationary because their positions are, for the main part, fixed by the spellings of their respective first hands.

Without doubt, this is the correct explanation. It serves as a warning not to read too much into my corrector spelling maps, unless a corrector is known to have made a systematic effort to change spelling throughout the analysed text. Fortunately, only the spelling maps of correctors are so affected, and maps for the first hands remain valid. To get a true picture of a corrector's spelling affiliation, it would be necessary to restrict spelling comparison to altered words rather than altered verses. This represents a significant programming challenge.

Although my corrector spelling maps should be regarded with a healthy skepticism, it is unwise to ignore them altogether. As noted before, U1s and U1-2 are thought to be one and the same scribe, so it is of interest to see how their positions compare in the spelling perspective. There are a

few spelling alterations which could move the spelling of U1-2 into a distinctive location, and the supplementary folio of Hebrews in Codex Sinaiticus provides plentiful examples to characterise the spelling of U1s. In the spelling maps, U1-2 is approximately equidistant from U2, U6, and P46, while its closest neighbour is U1. The spelling of U1s is approximately equidistant from U2, U6, and P46 as well. (The second U1s spelling map shows that parallax is to blame for the apparent proximity of U1s to U2 and U6 as compared with P46 displayed in the first map.)

As U1 does not appear in the U1s map (because scribe D's supplementary folio replaced scribe A's work), it is necessary to estimate its position in order to check whether it would have been the closest neighbour of U1s. The spelling map of U1 shows it to be quite close to a line drawn between U6 and U2. It turns out that U1s does, indeed, stand in close proximity to such a line, thus supporting the contention that U1-2 and U1s occupy corresponding positions. Even so, the most probable reason that U1-2 occupies a location near U1 is that the bulk of spellings used to determine its position are those of U1. The fact that U1s lies in a similar place indicates that Sinaiticus A and D spelled the same way, perhaps because they were compatriots.

Given that my maps tend to mix the spelling characteristics of a corrector with those of the first hand, the true position of a transitional corrector can be expected to lie further from the first hand than indicated by the plotted location. This probably applies to the spelling maps of U3-2, a corrector who has systematically revised the spelling of Codex Vaticanus. Extrapolation beyond the indicated position of U3-2 suggests a true location that is well on the way to group 3 spelling. Supposing that the spelling of U3-2 does conform to group 3 conventions, then this scribe might have been connected to the scriptorium at Caesarea. The hand is dated in the sixth or seventh century (Aland and Aland, 1989, 108), which happens to be around the same date as the 'C' group correctors of Sinaiticus.

Could it be that Sinaiticus and Vaticanus were both in Caesarea around the sixth century? Taken together with the suggestion that they came from the same scriptorium in Egypt, this points to a shared history for the

two great uncials, which only diverged after their stay in Caesarea. The only grounds for suspecting that U3 was in Caesarea is the apparent conformity of U3-2 to group 3 spelling. The fact that this corrector does not exhibit the same leaning in the textual perspective is a serious obstacle to the conjecture. Notwithstanding this, the possibility that U3-2 employs group 3 spelling deserves further investigation, but I will not attempt it here.

The spelling and textual maps indicate that U3-3, the scribe who retraced Codex Vaticanus, lies quite close to U3-2. Tischendorf dated U3-3 in the tenth or eleventh century 'chiefly because of the character of the minuscules into which he occasionally lapses' (Ropes, 1926, xl). No one knows where Vaticanus was at this time. Some have suggested Southern Italy. T. C. Skeat (1984, 463) hesitantly puts forward the conjecture that Codex Vaticanus 'was discovered, perhaps in Constantinople, shortly before the departure of the Greek delegation to the Reunion Council of Ferrara-Florence in 1438-39.' It is possible that the spelling adopted by U3-3 provides a clue to the location of Vaticanus when it was retraced.

Apparently, corrector U3-3 did not disagree with the spelling of U3-2, which, as we have seen, might belong to group 3. Among the manuscripts with this spelling, U18, U20, U25, U44, U75, and U150 date from the ninth or tenth centuries. This shows that group 3 spelling was in use around the time that U3-3 worked. If locality determines spelling, it follows that the codex was in the region that used group 3 spelling when it was re-linked. That would place Vaticanus in Palestine or Syria around 1000 CE.

This conjecture relies on a chain of assumptions, nearly all of which are speculative. As far as I know, a connection between spelling and locality is not proven, even though it is taken for granted in palaeography. The association of U3-3 with manuscripts that use group 3 spelling is not certain, and neither is the association of group 3 spelling with Syria and Palestine. The chance of such a valuable codex as Vaticanus being located in Syria or Palestine around 1000 CE seems slim indeed, unless it is assumed that the activities of a Christian scriptorium would have been tolerated at the time.

There are a number of alternative explanations for U3-3 following the spelling of U3-2. This corrector might have been content to leave the spelling as found, even though it did not conform to local standards. Then again, U3-3 might have made more spelling alterations if not constrained to those that can be achieved by not re-inking disapproved letters. The combined effect of the assumptions and uncertainties underlying the conjecture makes it extremely tenuous. The fact that the text of U3-3 belongs to group 2 and is stationary weakens the case even more.

Whereas the textual maps do not contradict the view that Sinaiticus D is one of the early correctors of Vaticanus, the spelling maps call it into question. As noted before, I am not sure whether U3-1 precedes U3-2. Even so, it is clear that neither has the same spelling affiliation as U1s because both are a significant distance from U2, which is a near neighbour of U1s in the spelling perspective. This is despite the fact that Milne and Skeat (1938, 90) use spelling as one of the criteria by which they judge Sinaiticus D to be similar to Vaticanus A. The result is not conclusive because the position of U3-1 is only based on eight units and appears suspiciously close to that of U3. It could be that an unbiased spelling analysis based on a sufficient sample size would locate the U3-1 near U1s.

The last category relates to divergent correctors and is comprised of scribes who altered their texts towards an unoccupied position. A position might be unoccupied because any manuscripts that would have been located there have all perished; but this is an argument from silence and it is reasonable to assume that such a position was never occupied. Therefore, divergent corrections probably represent innovations. In the textual perspective, this kind of activity is characteristic of an editor. In the spelling perspective, it implies that the corrector had peculiar spelling habits.

As far as corrected texts are concerned, U4-1, U6-1, U6-3, and U142-3 are divergent. It is possible that U6-1 is converging towards group 1, that U6-3 is converging towards group 3 or even group 1, and that U142-3 is converging on the Byzantine *Textus Receptus*. Only U4-1 is undoubtedly heading towards uncharted territory.

In the spelling perspective U1-2, U6-2, and U6-3 are divergent. As a corrector's location is unduly influenced by the spelling practices of its first hand in my spelling maps, it may be that a clearer tendency towards another group would be displayed if not for this interference. Even so, the divergent tendencies of U1-2 and U6-2 seem too pronounced to be attributed to systematic error. The divergence of U6-3 may be due to the cumulative effects of the divergent tendencies in U6-1 and U6-2. That is, its position could be affected by the mechanism that causes the spelling of an earlier hand to influence a later hand's location in my spelling maps.

Correctors marked with an asterisk have maps which exhibit a changed distribution of witnesses among groups as compared with the maps of their first hands. In some cases the change is spurious, being due to sampling error caused by a restricted sample size. In other cases, the change is genuine and is caused by an editorial proclivity to concentrate on certain words rather than to randomly select words for correction. As it happens, this phenomenon only affects the textual maps listed in the corrector dynamics table. This may be significant, indicating that a distribution change is more likely in textual maps than in spelling maps. In order to investigate this further, it is necessary to understand how intentional correction can cause a distribution change.

A distribution change can occur if a corrector has a specific model in mind. To make a manuscript conform, the corrector will concentrate on those words which differ from the model, and the same words will form the basis of the corrector's maps. This bias will tend to increase the relative distance from the first hand to manuscripts that resemble the model when a corrector's maps are compared with the corresponding first hand's maps. By contrast with this scenario, the corrector may have in mind a model that is not approved. Now those readings which do not differ from the model will be altered. Such a situation will tend to place the relevant first hand position nearer to those witnesses that conform to the model. Neither form of selective edition is guaranteed to produce a noticeable distribution change; it is possible that the changes of affiliation produced by such a selective approach to correction may be too slight to move any witnesses into uncharacteristic positions.

Apart from inconspicuous changes, the absence of a distribution change points to the absence of a model for corrections. Therefore, the lack of distribution changes among the listed spelling correctors could imply that a typical corrector tended not to use a specific model as a spelling reference. On the other hand, small sample sizes could be to blame for nearly all of the changed textual map distributions, making the observed difference between spelling and textual correctors of no consequence.

Even though their distribution changes may not be significant, the selective tendencies and distributional peculiarities of the marked correctors' textual maps will be considered individually. The distribution of witnesses in the P46-2 maps is unusual because, contrary to the usual situation, UBS4 is located near M2815, and U25 is relatively distant from U150. In addition to these quirks, the three groups tend to merge. No selective tendencies are evident, as P46 retains its usual affiliations. The same lack of distinction between groups occurs in the U44-1 maps as well. The first hand's nearest neighbours appear to be U25 and U150 in the U44-1 maps as well as the U44 maps, so the corrector does not appear to have been favouring one text or avoiding another. The U44-2 maps are unusual because they place U44 near U1 and M2815. If it were not for the combination of U1 and M2815, this would be an excellent illustration of selective editing whereby those readings of U44 that agreed with a M2815-like text *and* an U1-like text were rejected. However, the unlikely conjunction of U1 and M2815 compels us to attribute this distribution to random agreements in a small sample.

The proximity of U75 to P46 in the U75-0 maps can be interpreted to mean that the scribe was disturbed by P46-like readings and sought to change them. The scribe does not, however, seem to have been correcting towards a standard text, as indicated by the fact that U75-0 is stationary. The map of U142-1 indicates that this corrector selected readings in which U142 was unlike other manuscripts, then altered them towards a text like that of U56. By contrast, U142-3 seems to have selected against readings in which U56 and U142 agreed against other manuscripts, and altered them to a text like the *Textus Receptus*. Finally, the U150-1 maps have U150 away from its usual location near U25. This map seems to imply that U150-1 tended to alter words in which group 2

and group 3 texts agreed against the reading of U150. However, U150-1 does not appear to follow this with a correction towards either group.

Minuscules

Many of the textual maps derive from the sample data matrix which specifies readings for certain minuscules, versions, Fathers, authors, editions, and critical principles. These maps are generally based on fewer units than the maps derived from the primary witnesses, and only ever relate to textual variation. Maps corresponding to 'complete' primary witnesses are based on 728 units, whereas those of 'complete' sampled witnesses are only based on 71 units. The two classes of maps are analogous in many respects, although their disparate sample sizes and different arrays of witnesses combine to produce some differences.

The 'complete' sampled witness maps give the impression of a fairly uniform distribution of texts. Regions that correspond to the three groups discussed in relation to the primary witness maps can be identified in the sampled witness maps, but they are less well defined and tend to merge with one another. What I have called group 1 (roughly equivalent to Byzantine) texts congregate at one end of the first classical scaling axis, while group 2 (roughly equivalent to Alexandrian) texts lie toward the other end. A band extending between the first axis coordinates of M2127 and M81 defines an intermediate region that corresponds to my group 3 text, except that U2 and U6 are now included. The boundary lines defined by the first axis coordinates of M2127 and M81 are my choice and are not based on any natural group boundaries revealed by the sampled witness maps. In drawing these boundary lines, I have assumed that the group 3 witnesses of the primary witness maps actually comprise a distinct group as opposed to a spurious grouping that can be attributed to random phenomena.

The sampled witness maps convey information relevant to manuscript affiliations, textual inclinations of the versions, locations of Church Fathers relative to the other texts, and the kinds of texts commended by various editors and critical principles. Many of these maps are discussed below under their class headings. The distribution of witnesses found in 'complete' sampled witness maps (e.g., maps of M81, M104, and others

based on 71 units) forms the context within which the following comments apply. In general, only those maps which are based on more than fifteen units are considered.

This study would be much the poorer if it did not make reference to the minuscules. The sample data matrix approach has allowed certain readings from those minuscules included in the UBS4 apparatus to be incorporated in the analysis. Many of the minuscules have such interesting texts that they deserve full transcription. However, we must be content with this sample of readings for now.

Most of the minuscules lie in the group 1 region bounded by the first classical scaling axis coordinates of M2815 and M2127. Manuscripts such as M2815, U18, U56, U142, and U151 have already been classified as group 1. They form quite a compact group in the sampled witness maps as compared with the primary witness maps. There are a number of ways to account for this. The variation units chosen for the UBS4 apparatus may tend to underestimate the variation within this group. Then again, the variation between manuscripts such as M2815 and M2127 may be so large that variations between witnesses such as M2815 and U56-U142 appear to be small by comparison. It is not certain that minuscules near M2127 should be classified as group 1. Rather, they should be regarded as possibly belonging to group 1 or group 3.

Some minuscules lie in the region associated with group 2 texts that extends from the boundary defined by the first axis coordinate of M81. For example, M33 lies quite close to P46. Whether M81 should be classified as group 2 or group 3 is not certain. The same goes for M2464 and other witnesses in the vicinity of M81. In the sampled witness maps, M81 lies between P46 and U2, which are both group 2 in the primary witness maps. However, the sampled witness maps place U2 near U150, which is group 3 in the primary witness maps. Seeing that M81 appears to lie between a group 2 witness on one hand, and a witness that may be classified as group 3 on the other, I have chosen M81 to define the boundary of the regions associated with groups 2 and 3. To be sure of its affiliation, M81 would have to be transcribed in full so that its text could be subjected to a comprehensive comparison. The group 3 region is occupied by two of the sampled minuscules, M1175 and M1739.

There is some doubt as to the classification of M1175 because its closest neighbours appear to be U2 and U6. Neither of these fall into the group 3 category in the primary witness maps. In fact, those maps show that of all the witnesses with group 2 texts, U6 lies furthest from witnesses of group 3. The apparent shifts of U2 and U6 from group 2 in the primary witness maps to the region corresponding to group 3 in the sampled witness maps indicates a weakness in my tentative classification scheme. The shift of U2 may be due to a sampling error whereby its text happens to have a higher than expected proportion of group 3 readings among the variation units of the UBS4 apparatus. Another reason must be sought for the shift of U6. Perhaps the best explanation of this manuscript's variable affiliation is that it does not sit well in any of the three groups already proposed.

Versions

Fig. 3 gives a group classification for each version whose maps are derived from comparison of at least fifteen units. Once again, classifications are based on the regions of the sampled witness maps which I have identified as corresponding to the three text groups of the primary witness maps. Entries are arranged in order of their estimated composition dates. Estimates are not generally given for the Old Latin versions ('it' sigla) as each may represent a distinct translation from Greek of unknown date. The only exception is it-d, which is dated by virtue of its association with U6. (These two texts face each other in the bilingual Codex Claromontanus.)

The tendency for the earlier versions to be group 2 or 3 and for the later ones to be group 1 implies that the group 1 text did not become popular as a translation base until quite late. There does not appear to be a clear trend from group 2 to group 3, or vice versa, among the second and third century versions. This implies that neither the group 2 nor the group 3 text tended to dominate or to act as a powerful standardising influence in earlier times. However, there does seem to be a tendency for versions of the fourth, fifth, and sixth centuries to be based on the group 3 text.

Both of these observations depend on the given dates and classifications

being accurate. Unfortunately, the dates of many versions are not well established. Taking the Palestinian Syriac as an example, Metzger (1992, 71) says that 'most scholars think that it dates from about the fifth century', whereas it is given a sixth century date in the UBS4 introduction (1993, 27*). In addition, the classifications are not entirely reliable. Some of those classified as group 3 texts may, in fact, be nothing more than mixtures of group 1 and group 2 texts. By contrast with the primary witness maps, there is a fairly uniform spread of witnesses between the group 1 and group 2 regions. Therefore, distributional non-uniformity cannot be used to support the existence of a third group. Besides these uncertainties, there may be errors of classification caused by small sample sizes.

The patterns upon which these two observations are based could prove spurious, should the given dates and classifications require amendment. At the same time, new patterns with new implications may emerge. These reservations aside, the versional maps commend themselves by virtue of their frequent conformity to known historical circumstances of the witnesses they portray. The affinities displayed in the maps are generally consistent with scholarly assessments of their texts. What is more, the maps often reveal previously overlooked features that could help to reshape our picture of the textual history of Hebrews. The following version by version analysis compares established notions with the mapping results, highlighting fresh insights as they emerge. Where an established opinion concerning a version's text-type is given, the relevant authority usually refers to the Pauline epistles as a whole rather than Hebrews alone.

The Armenian version was produced at the beginning of the fifth century following the creation of the Armenian alphabet by Saint Mesrop (Metzger, 1977, 155). It was revised shortly afterwards:

After the Council of Ephesus (431), two Armenians returned from Constantinople with 'correct' copies of the Greek Bible (i.e. with MSS of the Lucianic text) and proceeded to bring the then existing Armenian text into conformity (*Oxford Dictionary of the Christian Church*, 1997, 107).

Streeter (1925, 104) suggested that these 'correct' copies were from

among the fifty manuscripts ordered from Caesarea by Constantine. More or less corrected to the Lucianic (i.e., Byzantine) standard, they were sold off or given away to provincial churches by the wealthier churches of Constantinople which had purchased pristine copies of the Lucianic text for themselves.

With regard to the textual character of the present Armenian version, Metzger (1977, 168) writes:

Preliminary analyses made by Lyonnet reveal that in Acts and the Pauline Epistles the version represents a mixture of the Alexandrian and Western texts in the proportion which is characteristic of the Caesarean text.

The Armenian version lies in a particularly interesting region of the sampled witness maps. This region, which is centred near M81, appears to be the nexus of a number of different strands of textual history, and could correspond to a particularly ancient text.

Metzger's statement about the textual nature of the Armenian version together with its location near the boundary of the group 2 and group 3 regions might be taken to imply that the Alexandrian and Western textual categories are equivalent to my group 2 and group 3 classifications, respectively. The first inference is reasonable enough, although the Alexandrian category seems to be broader than my group 2 classification. (The classification of M1739 serves to illustrate: this manuscript is usually described as Alexandrian but is definitely outside the group 2 camp according to the sampled witness maps.) The second inference is problematic because group 3 witnesses such as M1739, U25, U44, and U150 are not usually described as Western. Even so, it remains possible that some group 3 witnesses have been influenced by the Western text. It might be more appropriate to describe group 3 witnesses as Caesarean, given the association between group 3 and Palestine that has already been proposed. Whether group 3 witnesses should be described as Caesarean or Western or both remains an open question.

The Armenian version is thought to be based on an Old Syriac text (Metzger, 1977, 168). No copies of the Old Syriac Pauline epistles have survived, although Kerschensteiner demonstrated the existence of a

unified version that included Hebrews by studying the quotations of fifteen early Syriac authors. According to Metzger (1977, 44), Kerschensteiner regards this version as being akin to a text-type 'comprising many Western and some Alexandrian readings, similar to that current in Asia Minor during the second century.' If Kerschensteiner is correct then the Old Syriac would occupy a map location that corresponds to an old textual tradition in Asia Minor.

The extent to which the present Armenian version of Hebrews reflects the text of the Old Syriac depends on how closely the original Armenian translation followed the Old Syriac and the degree to which the present Armenian agrees with the original Armenian. No one can say how close the original Armenian is to the Old Syriac because neither version is extant for the Pauline epistles. According to the Alands (1989, 205), 'The first version had been made in the Persian area, where Greek literature was forbidden.' If Greek influences were minimal then there would have been less to draw the original Armenian away from the Old Syriac.

How close the present Armenian is to the original Armenian version depends on how thoroughly the revisers did their work. If they were meticulous then the present version would be more likely to reflect the 'correct' manuscripts brought back from Constantinople; otherwise, it would be closer to the Old Syriac basis. Consequently, the mapped location of the present Armenian version may equally reflect the location that would have been occupied by the Old Syriac text or the 'correct' text of the revisers.

With respect to the Coptic versions, the Sahidic and Bohairic are normally classified as Alexandrian, but the Bohairic has more Western readings. The Fayyumic is closer to the Sahidic than the Bohairic, in the Gospel of John at least (Metzger, 1977, 133, 138, 139). As the maps show that the Sahidic is group 2 and the Bohairic is group 3, these descriptions are only consistent if the Alexandrian classification encompasses at least part of the group 3 region as well as the group 2 region. It is difficult to give the Fayyumic version a group classification because its maps do not conform to the usual distribution of witnesses. Despite this, it can be described as resembling the Bohairic and Sahidic versions.

The Bohairic could lie where it does as a result of development towards the group 1 text. There is no doubt that this version originated in Egypt, so the issue turns upon whether the group 1 text exerted an influence in Egypt at the time the Bohairic version was developing. This seems most unlikely, given the early date of the Bohairic. As observed before, the group 1 text only appears to have become influential at a later stage. Besides, the prevailing view is that the Byzantine text did not even appear until the fourth century, which is after the Bohairic was composed. If the group 1 text cannot be blamed for the location of the Bohairic, another 'attractor' must be sought. In this context, an attractor is a text or textual group that exerts an attractive influence on other texts. That is, an attractor is a text that other texts converge towards.

The introduction to NA27 (1993, 68*) states that 'The Sahidic and Bohairic versions were made independently directly from the Greek.' This implies that the Sahidic has no influence on the position of the Bohairic, which should, then, give a good indication of the attractor's location. This would place the unknown attractor near the centre of the group 3 region, and not too far from the region surrounding M81 that has already been mentioned. (If the Bohairic was based on the Sahidic, then the attractor's true location would probably lie beyond the trajectory drawn from the Sahidic to the Bohairic.) Whatever the attractor was, it existed when the Bohairic was being composed. A possible identity for this attractor will be suggested after the Old Latin versions have been discussed.

Syrian Monophysites, who had fled to Ethiopia to escape persecution following their condemnation at the Council of Chalcedon (451 CE), are thought to have been instrumental in the translation of the Ethiopic version (Metzger, 1977, 221). Not much is known of this version's textual affinity in the Pauline epistles. Hoskier identified more than fifty readings where the Ethiopic is virtually alone in supporting P46, although his survey did not include Hebrews (Metzger, 1977, 232). There are indications that the Ethiopic version was translated directly from Greek. Metzger (1977, 233-4) summarises findings from a study of the Gospels:

Hackspill concluded [that the Greek base was] a Syrian or Syro-Western type of text, such as that represented by the Greek manuscripts (C) D E F G K and the Latin Vulgate. At the same time he acknowledged that the version does present a number of typically Alexandrian readings, agreeing with manuscripts B (C).

Metzger (1977, 235) also summarises the findings of an author who concentrated on the text of Acts:

Montgomery concludes that the Greek exemplar used by the translator approached the Antiochian, or Syrian, form but did not possess the polish of the latter, being, in fact, a fair example of the Oriental Textus Receptus of the day. At the same time, there are a number of coincidences with the Greek codex Vaticanus (B) and other early texts.

The maps show that the Ethiopic version lies in the region corresponding to group 3 texts. It lies near the group 1 boundary, making the description of 'Oriental Textus Receptus' just quoted for Acts appropriate for Hebrews as well. It is interesting to note that the Ethiopic and Syriac Peshitta lie in the same vicinity, as deduced from the proximity of both versions to manuscripts such as U25, M1739, and M1962. The Alands (1989, 197) write,

The very presence of Old Syriac readings in the Peshitta proves that it was not a new version but the result of a revision (or revisions) of a form of the Old Syriac text following an exemplar of a (mainly) Koine type text.

The date of the Peshitta revision is estimated to be early in the fifth century. That is, the revision of the Syriac New Testament using Greek manuscripts began just after Jerome commenced his revision of the Latin New Testament using Greek manuscripts. Once the Monophysites were compelled to flee from Syria, it is conceivable that those who went to Ethiopia took along copies of the same authoritative Greek manuscripts as had been used to revise the Syriac. These formed the basis of the Ethiopic version, with the result that the Syriac Peshitta and Ethiopic have close links. The maps imply that the Greek exemplars had the kind of text found in U25, M1739, and M1962, for Hebrews at least. The affiliation of the Ethiopic version with M1739 might account for its

agreements with P46. As noted by Zuntz (1953, 45), there is 'some close kinship' between M1739 and P46.

The textual nature of the Georgian translation is thought to stem from its Armenian and Syriac heritage. It shows signs of Greek influence, and has also been described as Caesarean (Metzger, 1977, 194-196). The manuscripts preserve two strains of the text which are designated Georgian 1 and 2. According to the Alands (1989, 205), 'This first translation (geo¹) was followed by a revision (geo²) based on a Greek text which was made after the separation from the Armenian church in the early seventh century'.

As far as the maps are concerned, Georgian 1 lies near the boundary of the group 1 and group 3 regions, which is consistent with it being described as a Caesarean text. Greek influence from manuscripts of group 1 is also evident; both versions show a tendency towards witnesses such as U18, a tendency that is more pronounced in Georgian 2. Georgian 1 does not appear to be closely related to the Armenian, as indicated by their disparate positions in the maps. (The Armenian is located near M81.) Instead, the basis of Georgian 1 seems to have been a group 3 text, or else group 3 manuscripts were consulted side by side with the Armenian version as translation proceeded. (The consulted manuscripts may also have been group 1, with a similar result.)

Georgian 1, the Syriac Peshitta, and the Ethiopic versions all lie in approximately the same vicinity and are roughly contemporary. This is probably not coincidental. As already seen, the resemblance of the Ethiopic and Syriac Peshitta can be attributed to historical circumstances. At about the same time that the Syrian church was revising its text, the Armenians were at work on their translation. Metzger (1977, 156) writes,

After creating the Armenian alphabet Mesrop gathered about him a band of keen scholars. Sending some of them to Edessa, to Constantinople, and as far as Rome in search of manuscripts of the Scriptures and of ecclesiastical and secular writers, he inaugurated a programme of translation which enriched and consolidated Armenian culture.

There is an Armenian tradition that Mesrop invented the Georgian

alphabet as well (Metzger, 1977, 184). Regardless of whether this is true, there were strong links between the Armenian and Georgian churches. Taken together with the account of the two Armenians returning from Constantinople with 'correct' copies of the Greek Bible, these points combine to suggest a scenario where fifth century scholars in the Syriac cultural sphere shared a determination to revise vernacular translations in the light of authoritative Greek manuscripts. What is more, the maps suggest that these authorities were aligned with group 3 texts such as U25 and M1739.

Unfortunately, the Armenian version itself does not appear to fit this scenario very well. The maps show that its text is near the boundary of groups 2 and 3 while the Syriac Peshitta, Ethiopic, and Georgian versions are near the boundary of groups 1 and 3. Why is this so? It is possible that the original Armenian version was not thoroughly revised in Hebrews with the consequence that the present Armenian stands close to the Old Syriac basis. Alternatively, the Greek exemplar used by the original Armenian version's revisers was not of the same kind as the Greek text that shaped the Syriac Peshitta, Ethiopic, and Georgian versions.

Jerome and Augustine agree that there were a multitude of Old Latin translations. Jerome wrote, 'There are almost as many different translations as there are manuscripts' (quoted in Aland and Aland, 1989, 187). Augustine says much the same thing:

Those who translated the Scriptures from Hebrew into Greek can be counted, but the Latin translators are out of all number. For in the early days of the faith, every man who happened to gain possession of a Greek manuscript and who imagined he had any facility in both languages, however slight that might have been, dared to make a translation (quoted in Metzger, 1977, 290).

Presumably the dates of these independent translations would have been just as varied. The earliest account of a Latin manuscript seems to come from the *Acts of the Scillitan Martyrs*, which relates to the Numidian persecution of 180 CE. One of the martyrs carried 'books and letters of a just man, one Paul.' Since this man was unlikely to have read Greek, the

books and letters were probably a Latin translation (Metzger, 1977, 289).

The Old Latin versions are typically classified as Western texts. Two forms are usually distinguished, with the African variety being further from today's critical text than the European variety. The existence of an Italian variety was suggested by Hort and accepted by some but rejected by others. More recently, a Spanish variety has been isolated (Metzger, 1977, 325-7).

Jerome published the Vulgate Gospels in 384 CE, the year after Pope Damasus commissioned him to revise the Old Latin. No one knows who completed the Vulgate New Testament, but its Pauline epistles are quoted by Pelagius in the early fifth century (Aland and Aland, 1989, 192). Harnack came to the conclusion that there were two pre-Vulgate Latin versions of Hebrews: a d-type represented by the Latin side of Codex Claromontanus (i.e., it-d), and an r-type represented by the Freising codex (i.e., it-r). He assigned these versions to the early third century, and thought that the Vulgate of Hebrews was mostly dependent on the d-type. Later, Diehl concluded that the Old Latin witnesses all depend on the d-type. SchŔfer thought that the r-type, perhaps translated from Greek by Augustine, affected the Vulgate after its composition (Metzger, 1977, 360-361).

Metzger (1977, 359) quotes Fischer's evaluation of the Vulgate's textual nature in the Pauline epistles:

The Vulgate is a revision according to a Greek text which was predominantly Alexandrian, but which nevertheless presented also several readings of the Koine and the Western texts. The Latin *Vorlage* stood close to the D-type with a mixture from the later stage of the I-type (pseudo-Augustinian Speculum, MS. 86, and especially MS. 61).

Presumably, 'D-type' refers to a Latin text of the type found in Codex Claromontanus (i.e., it-d), and 'I-type' refers to the text-type of Latin 61 (i.e., it-ar).

The maps confirm the existence of two kinds of Old Latin witnesses: those confined to the group 3 region, including Latin 61 (it-ar), 75 (it-d),

and 65 (it-z); and those which congregate near the boundary of the group 2 and group 3 regions, including Latin 89 (it-b), 109 (it-com), 64 (it-r), 56 (it-t), and 81 (it-v). (Some of these witnesses are represented by less than fifteen units. Their positions have been deduced by reference to near Latin neighbours. The position of it-r is the most uncertain, being based on only eight units.) I do not know whether these two kinds correspond to the African and European divisions of the Old Latin. If they do, then the ones near the boundary of the group 2 and group 3 regions would equate with the European type as they are less divergent from today's critical text (i.e., UBS4).

With respect to those Latin texts lying in the group 3 region, the proximity of it-ar to U25 suggests that they are related. The lack of other Latin witnesses in its vicinity implies that it-ar could be a translation of the kind of Greek text found in U25, which would make the it-ar text more recent than the U25 text. Given that the U25 text should be dated after the early fifth century, it follows that a text like it-ar could not have stood behind the Vulgate of Hebrews.

The Latin and Greek texts of Codex Claromontanus (respectively, it-d and U6) are also in close proximity, suggesting that one is dependent on the other. They share an idiosyncratic position when compared with the rest of the textual tradition. If a witness lies at the focus of a group of witnesses, it can be argued that it possesses a primitive text from which the others have sprung. Conversely, an isolated witness is probably a later textual development that has not existed long enough to give rise to many others of its kind. The text of Codex Claromontanus fits this last category, and can, therefore, be regarded as later rather than earlier. For this reason, it too is less likely to have been one of the Latin models for the Vulgate of Hebrews.

The Old Latin versions lying near the boundary of the group 2 and group 3 regions also lie near the Vulgate text (vg). This can mean that they represent the Old Latin basis of the Vulgate of Hebrews. If so, then the Vulgate is close to its basic Latin manuscripts, and any Greek manuscripts that might have been consulted during its composition did not have a significant effect on its textual affiliation. Alternatively, the texts of these Old Latin witnesses may be so influenced by the Vulgate

that they appear in the same area. In this case, they offer little help in locating the Latin basis of the Vulgate.

We know that Jerome consulted authoritative Greek manuscripts during his revision of the Latin Gospels. Whether the same was true for the reviser of the Pauline epistles is not known. Supposing that the reviser did make extensive use of Greek manuscripts, the maps may provide some clues concerning their nature. As a first observation, if the revision was thorough, the Old Latin base texts would lie a significant distance from the Vulgate's location. The only Latin witnesses that undoubtedly satisfy this requirement are it-ar, it-d, and it-z.

The antiquities of two of these texts, it-ar and it-d, have been drawn into question by their similarity to existing Greek texts. The third text, represented by it-z, is not affected in this way, so there is nothing to suggest that it could not have served as the basis for the Vulgate. If this was the Old Latin base text then the Greek authorities by which it was revised would have to be located beyond the Vulgate's relative position. This would place them in the vicinity of group 2 manuscripts. The it-z maps, while not being particularly well conformed to the usual distribution of witnesses, show that this is so. The Vulgate is located at an axis 1 coordinate of about 0.1. (In the it-z map-pair, it lies in the same position as the texts of Souter and Merk). Drawing a line from the position of it-z through the Vulgate's position and extrapolating beyond it, the hypothetical Greek attractor would be expected to lie along the projected line in a position which has an axis 1 coordinate of greater than 0.1.

There is a lack of agreement concerning what type of Greek text was used to revise the Old Latin basis of the Vulgate, but not a few scholars think that it was Alexandrian. Wordsworth and White suggest that Jerome's Greek text of the Gospels was of the type found in U1, U3, and U19, while J. H. Ropes concluded that the Vulgate Acts of the Apostles shows the influence of manuscripts such as U1, U2, U3, U4, and M81 (Metzger, 1977, 355-6). Streeter (1925, 594) thought that Jerome might even have used Codex Sinaiticus (U1) itself. In the Pauline epistles, Fischer thinks that the reviser consulted a predominantly Alexandrian Greek text. It is intriguing to note that U1 is one of the manuscripts lying

near the projected location of the reviser's Greek text if it-z is taken to be the Latin basis.

Even though the maps support a scenario of this kind, I do not think that it is possible to be confident that the Vulgate represents a revision of a group 3 text such as it-z, based on such limited evidence. The Old Latin texts surveyed here constitute a sample of only eight. Three of them are group 3, but two of these might be late translations. Four others are located close to the Vulgate, and a fifth one (it-r) appears to be in the same vicinity, but the small number of units makes this uncertain. (In fact, the maps of it-r show that it coincides with P46! Harnack may have been right to regard this as a primitive text.) On one hand, the possibility of Vulgate influence on the nearby Old Latin manuscripts makes us less confident that they represent its base text. On the other hand, the possibility that only one of the group 3 texts is primitive suggests that its variety of Latin text was relatively rare. As a consequence, there would have been less chance of it being in the reviser's hands.

An opportunity to label the region surrounding M81 now presents itself. The existence of an early attractor near the present position of M81 would help to account for the locations of the Armenian, Bohairic, Vulgate, and a number of Old Latin versions. Its influence on the Bohairic version implies that it was in Egypt by the third century. If the present Armenian version reflects the location of the Old Syriac then the same attractor may be the basis of the Old Syriac as well. All this is suggestive of the Western text, which, according to Metzger (1992, 214), is represented by the following witnesses in the Pauline epistles:

the Greek-Latin bilinguals DP EP FP GP; Greek Fathers to the end of the third century; the Old Latin and early Latin Fathers; Syrian Fathers to about A.D. 450.

Whereas a number of considerations suggest that the implied attractor is the Western text, others suggest it is not. The maps show that the Greek text most widely regarded as Western in Hebrews, U6, does not lie in the appropriate location. Also, the Vulgate may have caused the concentration of the Old Latin and Armenian versions in the vicinity of M81. As noted before, the Armenian version's location is inconsistent

with the textual nature of other versions in the Syriac domain that were revised in the fifth century. However, its position would be explained if the Armenian of Hebrews had been revised to conform to the Vulgate. This seems improbable from a linguistic perspective, but it is not impossible. If the concentration of witnesses near M81 is due to the Vulgate, the argument connecting this area with the Western text collapses.

According to Metzger (1977, 429), the Slavonic version is generally regarded as based on a Byzantine text 'but seems to be a development of that earlier form of the Koine that also lies behind the Syriac Peshitta of the fifth century.' There appears to be a Western influence as well, possibly due to the Papal rule that lessons had to be read in Latin before Slavonic (430). The maps show that the text lies in the group 1 region, making its description as Byzantine appropriate; but there is little to suggest influence from the Peshitta or a Western text.

The Syriac Peshitta has already been discussed in relation to the Ethiopic version. The Harklean Syriac revision, produced in 616 CE by Thomas of Harkel at Enaton Monastery near Alexandria, 'is an almost (though not absolutely) pure Koine type' (Aland and Aland, 1989, 199). The Palestinian Syriac version is more accurately described as a Palestinian Aramaic translation. The Melchite Christians who spoke this language were not confined to Palestine, but also settled in Egypt (Metzger, 1977, 76). There is a diversity of opinion on the subject of the version's date. Metzger (1992, 71) and the Alands (1989, 199) give a tentative fifth century date, while the UBS4 introduction (1993, 27*) places it in the sixth century. Concerning its text, Metzger (1977, 82) writes that 'the Palestinian Syriac version agrees with no one type of text, but embodies elements from quite disparate families and texts.'

The maps show that the Harklean version is indeed an almost purely Koine text, and that it is located quite close to Georgian 2. The Alands (1989, 205) date Georgian 2 to some time after the early seventh century. If the date is early seventh century, then not only the texts but the dates of the Harklean and Georgian 2 coincide. Their corresponding dates could account for their similar Greek bases. The existence of a strict textual standard would explain why both revisers had similar Greek texts

even though they were far removed from each other. Following this line, the Greek text that is reflected in the Harklean and Georgian 2 may be a 'snapshot' of the Byzantine Imperial text as it was in the early seventh century. This is not the only way to explain their resemblance. The revisers might have had similar Greek exemplars by coincidence or because they obtained them from the same centre, possibly in Syria.

The Palestinian Syriac appears to be affiliated with P46 and U150. This is a rather unusual combination, showing that Metzger's comment concerning its textual nature is justified. Considering the mapped locations of P46 and U150, it is fair to call the Palestinian Syriac a mixture of group 2 and group 3 texts. Given Palestinian provenance (which Burkitt did not accept: see Streeter, 1925, 76), and seeing that group 2 has been associated with Egypt and group 3 with Palestine or Syria, the textual and geographical situations of the Palestinian Syriac seem to correspond. Streeter (1925, 106) has already noticed this phenomenon:

If we look at the map we see at once that the Churches whose early texts we have attempted to identify stand in a circle round the Eastern Mediterranean— Alexandria, Caesarea, Antioch, (Ephesus), Italy-Gaul, and Carthage. The remarkable thing is that the texts we have examined form, as it were, a graded series. Each member of the series has many readings peculiar to itself, but each is related to its next-door neighbour far more closely than to remoter members of the series. Thus B (Alexandria) has much more in common with *fam.* Q (Caesarea); *fam.* Q shares many striking readings with Syr. S. (Antioch); Syr. S. in turn has contacts with D *b a* (Italy-Gaul); and, following round the circle to the point from which we started, *k* (Carthage) is in a sense a half-way house between D *b a* and B (Alexandria again).

If witnesses do tend to share readings according to their geographical proximity then, apart from textual mobility, their classical scaling map positions can be expected to reflect their geographical situations. As a result, their maps would approximate to actual maps of the Eastern Mediterranean.

Church Fathers

Fig. 4 relates to the Church Fathers whose citations are included in this thesis. It arranges these Fathers by date and provides their group classifications as well. The dates are estimates of when the Fathers were active, as determined from the relevant entries in the *Oxford Dictionary of the Christian Church* (1997). Some of the group classifications may be dubious, especially those based on smaller numbers of units.

In general, the smaller the number of units, the less the respective regions of the 'complete' sampled witness maps can be identified in the maps of the witness being classified. For this reason, I have employed an alternative classification method for Church Fathers represented by less than fifteen points. This method directly utilises the relevant dissimilarity matrix to identify a Father's nearest neighbours. The criterion for 'nearest' is a dissimilarity of less than or equal to 0.20. (In order to obtain reasonable numbers of nearest neighbours, values of 0.30 and 0.11, respectively, were used for Ephraem and Pseudo-Oecumenius.) Once identified, the nearest neighbours are classified according to the three regions of the 'complete' sampled witness maps, with split classifications permissible. These classifications are distributed between the three group categories to obtain a profile, with split classifications counting as votes for both relevant categories. The final classification is usually made according to the predominant category, but if another category has at least half as many votes as the predominant one, the final classification is split. When there are a number of group 1 witnesses that lie near the boundary of the group 1 and group 3 regions, they are treated as split between group 1 and group 3.

The classification of Eusebius serves to illustrate this method. Of the witnesses with dissimilarities of less than or equal to 0.20 relative to Eusebius, seventeen are classified group 1, none as group 2, four as group 3, and one as group 1-3. The split classification is counted as one vote for category 1 and one for category 3. The resultant profile is therefore seventeen plus one in category 1, none in category 2, and four plus one in category 3 (i.e., 18:0:5). This implies a group 1 classification, but for the four witnesses that lie near the boundary of the group 1 and group 3 regions (M104, M256, M1881, and M1962). If these are counted as split votes, the profile becomes 18:0:9. Group 3 now has at least half

as many votes as group 1, so the final classification is '1-3'.

This technique is more error-prone than the usual classification method because it is based on smaller samples. Also, it assumes that the total population of witnesses is equally distributed between the three groups. This assumption is not justified as group 3 witnesses are less numerous than their group 1 or group 2 counterparts. For this reason, a systematic error is introduced in which group 1 and group 2 classifications are expected to be more frequent than group 3 classifications.

Even so, the resulting classifications do not appear to be too far off the mark. It might seem that counting witnesses near the boundary between groups 1 and 3 as votes for group 3 introduces an unfair bias. In my opinion, this device is justified because a bias towards group 3 compensates for the systematic error just mentioned. Besides, it may be that these witnesses should be classified as group 3 in any case; a comprehensive rather than sampling approach is required to make the distinction sure.

Dividing the table in half, the profile for Fathers up to Gregory of Nyssa is 4:3:7 while the profile for those after him is 6:2:5. If there are any temporal trends in the table, they seem to be from less to more of group 1, and from more to less of groups 2 and 3, as time proceeds. However, the numbers are so evenly divided that none of these trends can be regarded as statistically significant. All this is consistent with the lack of correlation between date and derived coordinates of the Church Fathers that was noticed in the last chapter.

A number of the Church Fathers' texts may have been accommodated to other texts, although it is not possible to say how much this has occurred. Provided that the group 1 text should be regarded as an early fourth century creation, the group 1 leanings of Origen may be rejected as spurious. If so, the apparent temporal trend towards an increase in group 1 texts is slightly more pronounced, but is still not statistically significant. (Given that the probability of a group 1 text is about 0.5 for the table entries, the chance of getting three group 1 entries in one set of nine and six in another set of nine is about one in four when there is no trend.)

The group 3 text is present in almost the same numbers after Chrysostom as before. As such, it displays an unexpected degree of tenacity and persists well after the time that the group 1 text is supposed to have become the standard text. This same persistence was observed for the primary witnesses with group 3 texts and spellings. The group 2 text does not seem to have held on as long, with Cyril of Alexandria being its last advocate among these Fathers.

Place is an important consideration when it comes to the kind of text that a Father used. The observations just made concerning temporal trends may be invalid if the geographical distribution of the Fathers are significantly different in the two halves of the table. Fig. 5 lists the Fathers' locations along with their group classifications. Many of these Fathers spent time in various places. Hopefully, the locations listed here are the ones where they wrote on Hebrews. The geographical distribution of the Fathers is not the same in both halves. Fortunately, the disparity does not demand that the previous observations be changed. In general, Fathers from places associated with group 1 and group 3 texts are as well represented before and after the division. Accordingly, the observations regarding group 1 and group 3 texts stand. Fathers from regions associated with group 2 texts are more numerous in the first half than in the second. As it happens, there are more group 2 texts in the first half as well. Therefore, any group 2 trend between the first and second halves of the table is even less likely to be significant.

It turns out that many of the textual classifications in this table are consistent with the Fathers' locations when considered in the light of the tentative association between groups and places that has already been proposed:

Group 1: Constantinople (possibly encompassing Antioch)

Group 2: Alexandria (possibly encompassing Caesarea)

Group 3: Caesarea (possibly encompassing Antioch)

Broadening this scheme to regions, we obtain:

Group 1: Asia Minor (possibly overlapping Syria)

Group 2: Egypt (possibly overlapping Palestine)

Group 3: Palestine (possibly overlapping Syria)

Under this scheme, groups and locations correspond for Clement of Alexandria, Cyril of Jerusalem, Didymus, Ephraem, Chrysostom, Theodoret, and Pseudo-Oecumenius (assuming the UBS4 citations of Hebrews are for the same individual who wrote the commentary on the Apocalypse). The citations of Origen and Eusebius come into line if it is admitted that they have been contaminated by group 1 texts. Similarly, the texts and locations for Cyril of Alexandria and Theophylact are consistent if the possibility of contamination from group 3 texts is granted. Hence, eleven of the eighteen Church Fathers in this selection can be said to support the concept of correspondence between classical scaling and geographical maps without taking too many liberties with the data.

Other reasons must be sought to explain why the texts of some Church Fathers do not fit a theory of local texts. The text of Ambrose is located near the boundary of groups 2 and 3. This makes sense because he used a Latin text. As already seen, the Old Latin texts treated in this study lie within the group 3 region or near its boundary with the group 2 region. (How they came to be located in those places is another question. Interestingly, Zuntz (1953) drew an arrow from Caesarea to the origin of the Vulgate text in his 'Attempt at a graphic presentation' located at the end of *The Text of the epistles*.)

Textual mobility accounts for the incongruous textual affiliations of other Church Fathers. For example, under a local texts paradigm, Jerome would be expected to use a group 3 text consistent with his location in Bethlehem. However, a number of writers suspect that Jerome used a text like that of the Old Uncials, and this assessment agrees with my group 2 classification of his text. Jerome's use of a group 2 text would make sense if it was known that he consulted Egyptian manuscripts. In fact, Streeter (1925, 594) has already suggested that Jerome acquired some Alexandrian manuscripts while visiting Egypt in 386 CE.

Gregory of Nyssa's group 3 text is another case in point. According to my association between places and textual groups, Gregory's group 3 text

is not consistent with his location in Asia Minor. There is a plausible explanation for this: Gregory could have used a Greek manuscript that was related to one of the fifty imported from Caesarea by Constantine. Gregory was in contact with Constantinople and was active not too long after 331 CE when the Caesarean manuscripts were ordered. It is true that he spent a short time in Palestine, but this can hardly account for the nature of his text, unless his works that cite Hebrews were penned during his stay there.

While discussing characteristics of group 3 witnesses, I suggested that their resemblance might be due to a shared link with the Orthodox monastic movement. In his thesis on U48, Heath (1965, 4) mentions the influences of the Greek Orthodox Church in Southern Italy during the Middle Ages. Now the text of U48 is not group 3, but its spelling is. Supposing that the Greek-speaking monks of Southern Italy had links with a centre that used the group 3 text and spelling, it would not be surprising to find a group 3 text in the same place. Cassiodorus provides us with a text of precisely this kind.

In this context it is interesting to note that the writing imposed on U48 consists of sermons by Gregory of Nazianzus. As just noted, the text of Gregory of Nyssa, another of the Cappadocian Fathers, is group 3. Perhaps the centre that engendered the group 3 style in Southern Italy was not a centre but an organisation. That organisation may well have been the monastic movement that followed the rule of Basil, the third Cappadocian Father.

It is not surprising that John of Damascus has a group 1 text, even though a group 3 text might be expected. By the time he wrote, the Byzantine text may well have been the dominant Greek text in Palestine. Even if this was not the case, those copying his works in Greek might have progressively assimilated his citations to the Byzantine standard. The same kind of assimilation might account for the nature of Augustine's text, although the apparent lack of a Latin basis is puzzling; whereas his text does contain group 2 readings, it is almost devoid of the group 3 component expected of a Vulgate or Old Latin text. This may be due to nothing more than a sampling error associated with the small sample size of ten units.

This leaves the incongruous text of Athanasius to be explained. The possibility of sampling error is always present for classifications based on small numbers of units, and might account for his mismatched text. Even if the possibility of group 1 or group 3 contamination is allowed, the total lack of group 2 readings remains as a sticking point. In his work on Acts, Ropes (1926, cxcix) speaks of 'the demonstrated relation of Codex Vaticanus to Athanasius'. This implies that Athanasius has a group 2 text, in which case he should be added to those for which a theory of local texts is a sufficient explanation. It also implies that my textual classification of Athanasius is suspect. A greater number of his citations need to be examined to obtain a more accurate assessment.

In summary, about two-thirds of the classifications are consistent with a theory of local texts when textual groups are associated with regions according to the proposed scheme. The lack of correspondence between the texts and locations of Jerome, Gregory of Nyssa, and Cassiodorus can be explained as due to textual mobility. A non-Greek textual base accounts for the position of Ambrose. Standardisation or assimilation to the Byzantine text could provide the reason for the locations of Augustine and John of Damascus. The text of Athanasius seems to have been misclassified due to the small sample size.

A comprehensive study is required to discover more about the relationship between text and locality for the Church Fathers. Critical editions of the kind found in *The New Testament in the Greek Fathers* series published by the Society of Biblical Literature provide useful tools for this purpose. They would have even greater utility if exact transcriptions of patristic citations were published in a manner that allowed readings to be unambiguously associated with the manuscripts that contain them. Then the textual and spelling affiliations of individual patristic manuscripts could be revealed by multivariate analysis. All that can be obtained from present styles of patristic editions is an averaged text. Specific spelling characteristics are usually levelled so that information concerning this important aspect of individual texts is lost.

There is potential for significant progress to be made in understanding the transmission of the the Church Fathers' texts if the methods of the

present study are applied to their writings. The writings of the Church Fathers and the New Testament have been propagated through the same process of repeated copying. A spelling analysis could reveal where manuscripts were copied, thereby allowing manuscripts that are more likely to have been corrupted by the Byzantine text to be isolated. Some texts took more tortuous routes than others. Mapping each manuscript of a Father could reveal developmental trends that would identify one manuscript as a more reliable witness than another.

The texts of Gregory of Nyssa and Cyril of Jerusalem should be discussed before leaving the subject of the Church Fathers. Their texts were extracted from two volumes of *The New Testament in the Greek Fathers* series. Gregory of Nyssa's text is treated by James A. Brooks (1991, 252-261), who applies a number of classification methods to the text of the Pauline epistles. Using witness groups attributed to Metzger, he finds that:

The highest percentage of agreement is 69.2 with the Byzantine type, and there is a significant gap of 5.6% between it and the 63.6% agreement with the Later Alexandrian type (1991, 257).

Brooks later concludes that:

all of the evidence indicates that Gregory's quotations from the Pauline Epistles are orientated toward the Byzantine text-type, and it suggests but does not prove that he is a peripheral member of that type (1991, 261).

The term 'Later Alexandrian' used by Brooks refers to manuscripts such as U2 (A), U4 (C), U44 (Y), M33, and M1739 (1991, 256). In my classification scheme, these are group 2 or group 3 witnesses. The maps show that Gregory of Nyssa's text lies between the *Textus Receptus* and the UBS4 text, while being near group 3 witnesses such as U25, U44, and U150. Brooks' comments are generally consistent with the maps provided that the group 3 classification is taken to correspond to the 'Later Alexandrian' category. If my association between textual groups and geographical regions is correct, then the 'Later Alexandrian' label is a misnomer for manuscripts like U44 and M1739. A more appropriate term would be 'Palestinian' or 'Syrian', if not for the existing connotations of

these terms in New Testament textual research.

Cyril of Jerusalem's text is treated by Roderic L. Mullen (1997). Although Mullen characterises the text of Hebrews as 'the most Byzantine of any part of [Cyril's] text of the Pauline Corpus' (372), its conformity to the Byzantine text is not particularly strong. A table of percentage agreements (1997, 373) shows that the five nearest neighbours to Cyril's text are M1960 (60.0), TR (56.5), M1739 (52.2), M33 (50.0), and M88 (50.0). (The figures in brackets are percentage agreements.) After declaring three of these to be Byzantine (M1960, TR, and M88) and two Alexandrian (M33 and M1739), Mullen (1997, 372) writes that 'The Byzantine nature of three of the five highest ranking witnesses suggests that Cyril's text is Byzantine'. He also performs a 'group profile analysis', following a method devised by Bart D. Ehrman. The resultant profiles (1997, 374) show that Cyril's text is more Byzantine than Alexandrian, but is not closely related to either.

The maps place Cyril of Jerusalem's text near group 3 witnesses such as U25 and U150, and between the *Textus Receptus* and the UBS4 text, which is in an almost identical location to the one occupied by Gregory of Nyssa's text. Cyril's isolation from both the Byzantine and Alexandrian camps is consistent with Mullen's figures, if not with his conclusion that the text is Byzantine. Apparently, this is a case where the maps allow us to perceive relative dispositions that are not terribly clear from tables of percentage agreements. The placement of Cyril's text near group 3 witnesses is supported by its relatively close relationship to M1739. Whereas this manuscript is often classified as Alexandrian, it falls within the group 3 region of the maps. The plotted position of Cyril's text is roughly equidistant from the group 1 and group 2 regions. This is consistent with the presence of both group 1 (i.e., M88, M1960, and TR) and group 2 (i.e., M33) witnesses among its nearest neighbours.

As already mentioned, the texts of Gregory and Cyril appear to occupy almost identical map positions. Both texts are highly unusual because their nearest neighbours, as revealed by inspection of the dissimilarity matrices, are the *Textus Receptus* and the UBS4 text. The fact that the maps of Gregory and Cyril place the *Textus Receptus* and the UBS4 text near these Fathers and away from their usual positions is consistent with

this state of affairs. As far as I know, the texts of these two Fathers are the only ones among all of the surveyed texts that display this characteristic. This strikes me as suspicious, and suggests that there is a methodical bias in these two volumes of *The New Testament in the Greek Fathers* series that tends to favour the *Textus Receptus* and the UBS4 text above all other texts when reconstructing patristic texts. This bias would be eliminated by giving the exact text of the Fathers' citations instead of a text that has been influenced by standard texts in any way.

Assuming that the methodical bias has not affected the map locations of Gregory and Cyril too much, they both appear to have group 3 texts. The corresponding volumes of *The New Testament in the Greek Fathers* series show that these Fathers seldom quote from the same parts of Hebrews. Nevertheless, the mapping technique indicates that they used the same kind of text. This highlights a particular strength whereby classical scaling can ascertain the relative disposition of two fragmentary texts that have little or no extant text in common.

Authors and editions

Maps for the Greek texts preferred by a number of authors and editions have been produced as well. Nearly all are based on sampled texts incorporated via the sample data matrix. Consequently, they conform to the general pattern exemplified by the 'complete' sampled witness maps based on 71 units. The *Textus Receptus* and UBS4 text represent comprehensive transcriptions so their principal maps are based on 728 units. Being complete, they appear in the sampled witness maps as well.

The editions of Von Soden, Vogels, Souter, Merk, and Bover appear to be situated along a trajectory that runs from the Vulgate (located near M81) to the text of Tischendorf's eighth edition. If this were the case, their texts could be approximated by selecting readings from Tischendorf or the Greek underlying the Vulgate and ignoring all other witnesses. In fact, the situation is not as simple as suggested here. The dissimilarity matrix of the Vulgate text shows that the given order is preserved when dissimilarities are measured relative to Tischendorf: Vulgate (0.24), Von Soden (0.14), Vogels (0.13), Souter (0.10), Merk (0.06), Bover (0.03), and Tischendorf (0.00). However, the order is upset once the Vulgate is

taken as the reference point: Vulgate (0.00), Merk (0.21), Souter (0.24), Bover (0.24), Tischendorf (0.24), Von Soden (0.29), and Vogels (0.30). (The figures in brackets are dissimilarities.) Therefore, it is true to say that these editions lie on a trajectory that leads away from Tischendorf's text, but it is not true to say that the trajectory leads towards the Vulgate.

The texts of Westcott and Hort, Nestle-Aland's 25th edition, and the United Bible Societies' 4th edition are quite close to each other, as should be expected. The preferred texts of the recent commentary authors Attridge, Bruce, Ellingworth, Lane, and Tasker form a cluster centred between the three texts just mentioned and texts of the kind found in P46. This location is consistent with the authors starting with the UBS4 text and occasionally following the P46-like text when the two differ. The texts of P46 and Codex Vaticanus (U3) are quite similar, up to Heb 9.14 at least. That the commentary authors tend to be influenced by the texts of P46 and U3 is not surprising given the generally high esteem in which these manuscripts are held.

The text preferred by Zuntz is not far from P46 as well. His opinions seem to be quite influential, judging by the number of times the commentators follow his textual decisions. He set out to treat each variant on its own merits:

My main concern, however, was to build upon safe foundations, and these lay in the assessment of individual variants. It is not enough to assert that this or that reading 'seems attractive' or 'was rejected by Westcott and Hort'. Readings are either right or wrong. The plain, primary purpose of criticism is to establish the right wording (Zuntz, 1953, viii).

If he has succeeded in establishing the right wording, then the mapped location of his preferred text should not be far from that of the original text. The possibility remains, however, that he has been unduly swayed by P46 and U3 as well.

George D. Kilpatrick's amended text is in a position of its own, as might be expected from his thorough-going eclectic approach. This text's unique location demonstrates that the exercise of editorial judgment can be associated with divergence. Bearing in mind that divergence might be

convergence towards a position that is no longer inhabited, Kilpatrick's text could be converging towards the position once occupied by the original text. While possible, the distribution of other witnesses indicates that this is improbable.

The *Textus Receptus* is nowhere near the other editions. Its location at the Byzantine textual pole is entirely consistent with the historical circumstances surrounding its creation. As is well known, Erasmus obtained Byzantine manuscripts from the University of Basel, corrected them as he saw fit, then presented them to Froben for printing. The resulting volume was published in 1516, and later revisions came to be known as the *Textus Receptus*.

At this point, it is pertinent to ask what map position the original text should be expected to occupy. With the exception of the *Textus Receptus*, all of the surveyed authors and editions prefer texts situated in the group 2 region. If the consensus of modern minds is a reliable criterion for establishing the original text then this text's mapped location would be in the group 2 region.

Criteria

Of the twelve criteria incorporated in the sample data matrix, the 'elemental' and 'stable' criteria are not mapped because they are represented by less than five units. The 'combined' criterion represents the majority vote of the other criteria concerning preferred readings.

In an unexpected result, the text preferred by the 'explanatory' criterion (that is, 'prefer the reading that explains the origin of the others') appears to be close to the text of U6. This is confirmed by examination of the dissimilarity matrix, which shows that the texts of U6 and Kilpatrick are its nearest neighbours. (Both have a dissimilarity of 0.29 relative to the 'explanatory' text.)

Application of the 'manifold' criterion results in a text located near the boundary of the group 2 and group 3 regions. This area is occupied by the Armenian, Vulgate, a number of Old Latin versions, and manuscripts such as U2, M33, and M81. It is fitting that a text characterised by the

agreement of ancient groups of witnesses should lie here.

The 'prevalent' criterion maps have an unusual distribution of witnesses that makes it difficult to classify the criterion's text according to the usual categories. The dissimilarity matrix shows that the nearest witnesses are the Byzantine text, Von Soden, and M2815, which all have a dissimilarity of 0.14. The maps correctly place the 'prevalent' criterion between these three, but give a misleading impression of resemblance with U2. In this respect, three dimensions are insufficient to convey the true situation. It is not surprising that the 'prevalent' criterion is near Byzantine witnesses, given that they constitute the most prevalent class.

The 'authentic', 'difficult', 'discordant', 'short', 'diverse', 'early', and 'reliable' criteria all commend texts that fall within the group 2 region, as does the 'combined' criterion. A common characteristic of the texts constructed according to these criteria is proximity to witnesses such as P46 and U3. Given that the consensus of criteria is a reliable guide, the original text of Hebrews would have been close to the texts of these two manuscripts.

These criteria are not infallible. As with the preferred texts of the authors and editions, supposedly independent critical judgments can be influenced by particular witnesses, authors, and editions. Manuscripts such as P46 and U3 seem to exert a powerful attraction, and the textual decisions of Zuntz are often followed in the commentaries. Many of the critical judgments deposited in the sample data matrix can be traced back to him. Also, it is probably fair to say that a modern commentator is more likely to reject a reading found in the *Textus Receptus* than a reading found in the UBS4 text, other things being equal. It follows that an unfair discrimination prevails against readings that happen to occur in Byzantine manuscripts. It would be better if all readings were presumed innocent until proven corrupt.

Another failure occurs when fundamental critical assumptions make different criteria equivalent. This creates an illusion of consensus when all that actually exists is dependence of one criterion upon another. For example, if the shorter reading is regarded as more primitive under all circumstances, the 'shorter' and 'explanatory' criteria will produce the

same results. This is because the shorter reading will be assumed to be the origin of more verbose ones.

Only independent approaches to finding the most probable original text can avoid tautology and an illusion of consensus. Studies of the kind undertaken by Royse (1981) provide the groundwork for principles that choose between genuine and spurious readings by reference to observed scribal tendencies. A set of independently formulated principles of this kind could operate as a panel of independent judges that assesses each reading in the light of its freedom from the respective modes of corruption. Tried and true criteria could be used as well, provided that care was taken to maintain their independence of each other. In order to do this, any criterion that was shown to depend on another would have to be discarded.

Kilpatrick's thorough-going eclecticism has been criticised for paying scant regard to manuscript evidence. Given that independence is a desirable characteristic, this strategy is actually commendable. The same can be said of the approach taken by Bernhard Weiss, who selected readings that he thought were consistent with the author's style (see Metzger, 1991, 137-8). While admittedly subjective, the independent character of a text founded on this principle makes it valuable.

The text preferred by each independent criterion is an independent approximation to the original text. Concurrence of such texts can provide a certainty about the wording of the original text that surpasses the certainty of any reconstruction founded on a single criterion:

The convergence of arguments drawn from the distribution of the evidence, the dependence of one reading upon the other, the known habits and typical faults of scribes, the characteristic proclivities of interpolators, the development of the language, the stylistic peculiarities of the writer, the context of the passage in question Ñ these, and still other, factors combined can yield a certainty which is no whit inferior to that of the conclusions drawn from a Euclidean axiom (Zuntz, 1953, 13).

These independent approximations to the original text can be subjected to the classical scaling procedure, thereby producing maps. If the

approximations tend to cluster in a certain region, then it is reasonable to conclude that the original text would lie in the same area. Hence, a new critical principle emerges: 'prefer the text that is closely affiliated with texts constructed according to independent and reliable critical principles, provided that a majority of these form a group.' (The next chapter will discuss ways of determining what constitutes a group.) Although this criterion relates to entire texts, it can be indirectly applied to individual readings. Westcott and Hort (1881b, 32) used the principle that the readings of a trustworthy document were likely to be trustworthy themselves:

Where then one of the documents is found habitually to contain these morally certain or at least strongly preferred readings, and the other habitually to contain their rejected rivals, we can have no doubt, first, that the text of the first has been transmitted in comparative purity, and that the text of the second has suffered comparatively large corruption; and next, that the superiority of the first must be as great in the variations in which Internal Evidence of Readings has furnished no decisive criterion as in those which have enabled us to form a comparative appreciation of the two texts.

By analogy, the readings of witnesses that lie within a cluster of independent approximations to the original text are more likely to be those of the original text than are the readings of distant witnesses.

Another approach focusses on reading-by-reading decisions: 'prefer the reading selected by a majority of independent and reliable critical principles.' This would result in a single text that should be located in the same region of a classical scaling map occupied by a majority of independently constructed critical texts.

Summary

Textual and spelling maps

There appear to be three broad textual groups among the primary witnesses (i.e., those which have been fully transcribed). Whether these should be divided into more groups is not clear. Nevertheless, a division into three groups is assumed. A tripartite partition is also evident in the

spelling maps. Many witnesses have the same affiliations in the textual and spelling perspectives, while others have differing affiliations depending on the perspective.

A working theory is proposed to account for this phenomenon. It begins with heredity to explain affiliation in the textual perspective, so that community of readings implies common ancestry. The existence of centres is attributed to primitive archetypes. Affiliation in the spelling perspective is assumed to be caused by assimilation of spelling to local standards, so that community of spelling implies common locality. The theory assumes that texts were mobile, that scribes treated textual and spelling variations differently, and that spelling is related to locality. Clustering is better defined in the spelling maps than in the textual maps. This is consistent with spelling peculiarities being more volatile than textual peculiarities, as assumed in the theory.

Provided that spelling and locality are related, an association can be drawn between spelling groups and geographical centres. Even though it is difficult to be confident of the associations, the following scheme is proposed:

Group 1: Constantinople (possibly encompassing Antioch)

Group 2: Alexandria (possibly encompassing Caesarea)

Group 3: Caesarea (possibly encompassing Antioch)

If spelling corresponds to locality and this scheme is correct, then P13, P46, U1, U2, U3, U6, and U16 probably come from Egypt.

With respect to individual spelling transformations, each direction of change contributes distinctive information to the overall picture. The picture obtained by combining all of the bidirectional transformations is not generally discernible in the constituent transformations. Hence, any manuscript characterisation based on a single spelling transformation is prone to failure.

Other maps

Patterns of agreement found in the 'other' maps (i.e., maps related to peripheral features such as line-divisions and punctuation marks)

generally differ from those found in textual and spelling maps. The UBS4 text does not follow the same punctuation practices as uncial manuscripts but does divide the text in a similar manner to U2. There appears to be a relationship between U25 and M2815 in peripheral features but not in spelling and text. This is a perplexing result that calls for further investigation. An increased use of punctuation with time may account for part of the overall structure seen in the punctuation maps.

The patterns of affiliation seen in the 'other' maps suggest two processes by which agreements can occur between otherwise unrelated manuscripts. One is the application of rules, whereby independent scribes would be compelled to arrive at the same features. Spelling agreement is a special case of this mechanism in action. Another process is agreement by coincidence.

Correctors

The analysis of corrector maps uses dynamic terms such as stationary, transitional, and divergent to describe change. As should be expected, scribes who have corrected their own work are generally stationary. The second hand (i.e., the first corrector who could be a *diorqwthv*") also tends to be stationary. Transitional correctors generally move towards group 1 or group 3, while none move towards group 2. As correctors always post-date their first hands, this implies a temporal trend away from the group 2 text, predominately towards the group 1 text. To use roughly equivalent conventional terminology, the text of Hebrews was revised away from the Alexandrian text and towards the Byzantine text as time progressed.

Limited data makes these conclusions on temporal trends among correctors hazardous. From the data at hand, there seem to have been episodes of correction towards group 1 then group 3. This result could quite easily change if more correctors were analysed. Also, what appears to be correction towards group 3 could be partial revision towards group 1. However, the non-uniform distribution of primary witnesses implies that the third group is a distinct entity.

A change of witness distribution among groups for certain correctors may indicate a selective approach to correction. The lack of distribution

changes among corrector spelling maps could imply that a typical corrector tended not to use a specific model as a spelling reference.

Some attention is devoted to the scribes and correctors of Codex Sinaiticus. This table helps to clarify what follows:

U1: Sinaiticus A. Responsible for all except the supplement.

U1s: Sinaiticus D. Responsible for the supplement.

U1-2: Tischendorf's 'A' corrector(s).

U1s-2: No such alterations exist.

U1-3: Tischendorf's 'C' corrector(s).

U1s-3: Tischendorf's 'C' corrector(s).

The text of U1 (i.e., Tischendorf's scribe A) is almost identical to the text of U2. By contrast, the text of U1s (i.e., Tischendorf's scribe D) is closer to P46, U3, and U6. This implies that U1 and U1s relied on different exemplars. These two scribes spelled in a similar way. If community of spelling implies common locality, then they learned to spell in the same region.

Palaeographical considerations imply that U1-2 is U1s correcting text copied by U1. This explains why there are no alterations to the work of U1s by the second corrector. The textual maps are consistent with U1s being identical to U1-2. They are also consistent with U1-3 and U1s-3 being one and the same corrector

Tischendorf thought that Sinaiticus D was Vaticanus B. Whereas Lake rejected this, Milne and Skeat saw similarities between Sinaiticus D and Vaticanus A. The textual maps are consistent with this conclusion as well.

Lake thought that Tischendorf's 'C' correctors worked at the Caesarean scriptorium in the fifth or sixth century and accommodated the text of Sinaiticus to a Caesarean model. This group of correctors corresponds to U1-3 (who is also U1s-3) in Hebrews. The association of U1-3 with Caesarea and the third textual group suggest that the group 3 text corresponds to a text current in Caesarea during the fifth and sixth centuries.

The spelling of the 'C' correctors does not converge on group 3. Their positions are strongly influenced by the spellings of their respective first hands. This is a systematic error that affects all of the corrector spelling maps. As a consequence, implications drawn from the corrector spelling maps must be treated with caution until this error is corrected.

Turning to Codex Vaticanus, the spelling of U3-2 might conform to group 3 conventions. This scribe is dated in the sixth or seventh century. Taken together, the date and apparent spelling affiliation imply a connection with the scriptorium at Caesarea. If so, then it is possible that Sinaiticus and Vaticanus had a shared history that only diverged after their stay in Caesarea. This conjecture is weakened by the fact that the text of U3-2 does not have the same leaning towards group 3. The spelling of U3-3 also appears to be group 3. This might be taken to imply that U3 was in a locality associated with group 3 spelling when it was re-linked. Spelling considerations go against the contention that Sinaiticus D is one of the Vaticanus correctors. In view of the systematic error and uncertainties caused by small sample sizes, these implied results should be regarded as little more than speculations.

Sampled witnesses

Maps derived from sampled witnesses only relate to textual variation. They are based on a maximum of 71 units compared with a maximum of 728 units for primary witnesses. Maps of primary and sampled witnesses are generally analogous but do not correspond exactly. My tentative classification scheme divides the first classical scaling axis of sampled witness maps into three regions that correspond to the three groups evident in the primary witness maps. Region boundaries are at the first axis coordinates of M2127 and M81:

Group 1 É M2127 É Group 3 É M81 É Group 2

These manuscripts have been chosen to define the boundaries because they seem to be located at points of the sampled witness maps that correspond to midway points between groups in the primary witness maps. As there are no clear group divisions in the sampled witness maps, it is better to regard M2127 and M81 as marking fuzzy transition zones

rather than crisp boundaries. Also, witnesses near M2127 and M81 should be regarded as possibly belonging to either of the respective groups. For example, a witness near M2127 may belong to group 1 or group 3. The sampled witness classification scheme does not place U2 and U6 in the same groups as the primary witness classification scheme. This may be due to sampling error for U2, or the lack of an appropriate group for U6. Most of the minuscules lie in the group 1 region, while a few are in the group 2 and group 3 regions.

Versions

Maps of the versions imply that the group 1 text did not become a popular translation base until the seventh century. Group 2 and group 3 texts were popular translation bases in the second and third centuries. Group 3 texts seems to have been the preferred translation base in the fourth, fifth, and sixth centuries. These results are provisional because they rely on small sample sizes and uncertain dates.

The present Armenian version might give the location of the Old Syriac. This, in turn, could give the location of an ancient text of Asia Minor. The present Armenian might also give the textual location of manuscripts used to revise the original Armenian version..

The basis of the Georgian versions seems to have been a group 3 text but not the Armenian, which stands near the border of groups 2 and 3. Georgian 1, the Syriac Peshitta, and the Ethiopic all have group 3 texts and were composed about the same time. This suggests that there was a widespread desire to revise vernacular translations according to Greek manuscripts (specifically group 3 texts) in the Syriac cultural sphere during the fifth century. The Armenian version does not fit into this scenario because its text stands a significant distance from the other three.

There are two basic varieties of Old Latin manuscripts. One consists of group 3 texts, two of which may well be late. Consequently, they can be ruled out as possible base texts for the Vulgate. The other variety is comprised of manuscripts that lie near the boundary of groups 2 and 3. These might represent the kind of text used as a basis for the Vulgate. Then again, they might have been contaminated by Vulgate readings.

This would make them less useful for locating the Vulgate's Old Latin base.

Given that the Vulgate was a thorough revision, it should be located at an appreciable distance from its Old Latin basis. The group 3 Old Latin manuscripts are sufficiently distant to be considered as possible base texts. The two potentially late manuscripts can be excluded, leaving it-z as a plausible candidate. If this manuscript does represent the Old Latin basis of the Vulgate then the Greek texts used by the reviser would have been similar to the text of U1. As usual, a lack of data makes these results quite tenuous.

The Armenian, Bohairic, Vulgate, and some of Old Latin versions congregate in one area of the sampled witness maps. This suggests that a text located near their present locations exerted an attractive influence during an early phase of textual development. The Western text would provide a suitable identity for this 'attractor', except that the position of U6 and the possibility of Vulgate influence makes the conclusion uncertain.

The textual and geographical situations of the Palestinian Syriac seem to correspond. A correspondence between texts and localities has already been observed by Streeter. If such a correspondence does exist, classical scaling maps should approximate their geographical counterparts for the Eastern Mediterranean.

Fathers

As far as group affiliations are concerned, no definite temporal trends can be discerned among the texts of the Church Fathers. If there are any trends, the prevalence of group 1 texts increases, and group 2 texts become less common. Group 3 texts are surprisingly persistent.

Many of the Church Fathers' textual classifications are consistent with their locations when a broadened scheme of association is employed:

Group 1: Asia Minor (possibly overlapping Syria)

Group 2: Egypt (possibly overlapping Palestine)

Group 3: Palestine (possibly overlapping Syria)

Groups and locations correspond for about two-thirds of the Fathers. The textual affiliations of Fathers whose texts and locations do not correspond can be attributed to textual mobility, non-Greek textual bases, assimilation to a Byzantine standard, or errors associated with small sample sizes.

Exact transcriptions of individual patristic manuscripts are desirable so that multivariate analysis can reveal textual and spelling affiliations on a manuscript by manuscript basis. In this way, the effects of assimilation and other developmental trends would be easier to see.

Attention is focussed on Gregory of Nyssa and Cyril of Jerusalem because their texts are treated in the Society of Biblical Literature's *The New Testament in the Greek Fathers* series. Classical scaling maps show that their texts are similar even though they do not exist for the same portions of text. That is, the classical scaling procedure can ascertain the relative disposition of two fragmentary texts that have little or no extant text in common.

The maps also show that the texts of Gregory of Nyssa and Cyril of Jerusalem share a distinctive trait not otherwise seen: their closest neighbours are the *Textus Receptus* and the United Bible Societies' 4th edition. Apparently, there is a methodical bias in these volumes of the series that tends to favour standard texts above all others when a Father's text is being reconstructed.

Authors and editions

All surveyed authors and editions except the *Textus Receptus* prefer texts in the group 2 region. If consensus of modern minds is a reliable guide then the original text would lie there as well.

Criteria

Nearly all texts preferred by the criteria lie in the group 2 region. Many of them point to the area occupied by P46 and U3. If consensus of criteria is a reliable guide then the original text was similar to the texts of these two manuscripts.

The existing method of applying critical rules to discern the most likely original text can be improved by using independent criteria that have been formulated on the basis of observed scribal tendencies. Concurrence of independent criteria creates confidence regarding the wording of the original text. Two new critical principles are suggested:

(1) 'Prefer the text that is closely affiliated with texts constructed according to independent and reliable critical principles, provided that a majority of these form a group.'

(2) 'Prefer the reading selected by a majority of independent and reliable critical principles.'

Fig. 1: Dynamics of corrector texts and spellings

<i>Scribe</i>	<i>Text</i>	<i>Spell.</i>	<i>Comments</i>
P13	2	2	
P13-1	2 S	-	
P46	2	2	
P46-0	2 S	2 S	
P46-1	2 S	2 S	
P46-2	?* T	-	Text (17 units) -> U18.
U1	2	2	
U1-0	2 S	-	
U1-2	2 S	2 D	Text -> P46.
U1-3	3 T	2 S	Text -> group 3 (or 1?)
U1s	2	2	
U1s-3	2-3 T	2 S	Text -> group 3 (or 1?)
U3	2	2	
U3-1	2 S	-	Text -> U25?
U3-2	2 S	2 T	Text -> P46-U2. Spell. -> group 3?
U3-3	2 S	2 T	Spell. -> group 3.
U4	2	1	Different groups.
U4-1	2 D	1 S	Spell.: may be divergent.
U4-2	1-3 T	? S	Text -> group 1. Spell.: group 1, diffuse for these units.
U4-x	? D	-	Corr. 1+ corr. 2.
U6	2	2	
U6-0	2 D	-	
U6-1	2 D	2 S	Text -> group 1? May be divergent. Spell. -> P46-U2?
U6-2	1-3 T	2 D	Text -> group 1.
U6-3	? D	2 D	Text -> group 3? (or 1?)
U6-x	? D	2 D	Text -> group 1. Spell.: corr. 1 + corr. 2.
U15	2	3	Different groups.
U15-1	2 T	2-3 S	Text -> group 1. Spell.: shift due to sampling error?
U18	1	3	Different groups.
U18-0	1 S	-	
U20	1	3	Different groups.
U20-2	1 S	3 S	Text: U18-U151 near U25-U150. Spell.: loose affiliation.
U44	1-3	3	
U44-1	?* S	-	Text (20 units).
U44-2	?* T	-	Text (22 units) -> M2815 or U56-U142: selective correction?
U75	1	3	Different groups.
U75-0	?* S	3 T	Text (45 units): selective correction? Spell.: centralisation.
U122	1	1	Text (26 units): unusual witness distribution.
U122-1	1 S	-	
U142	1	1	
U142-1	1* S	-	Text (36 units) -> U56; groups 2 and 3 merge.
U142-3	1* D	-	Text (22 units) -> TR? Unlike U18-U151.
U142-x	1* D	-	Text (23 units): corr. 1 + corr. 3.
U150	3	3	
U150-1	?* S	-	Text (33 units): unlike 2-3; selective correction?

1, 2, 3 = groups, as defined before

X-Y = may belong to group X or group Y

? = affiliation not clear (? = uncertainty in comments section)

* = distribution change: corrector maps not like maps of first hand

S = stationary: not much movement

T = transitional: significant movement towards other witnesses

D = divergent: significant movement, but not towards other witnesses

-> = 'converges towards'

Fig. 2: Temporal trends for correctors

<i>Corrector</i>	<i>Date</i>	<i>Tendency</i>
P46-2	275	-> 1 (or 3?)
U4-2	550	-> 1
U3-2	600	-
U1-3	650	-> 3 (or 1?)
U1s-3	650	-> 3 (or 1?)
U6-2	650	-> 1
U6-3	850	-> 3 (or 1?)
U20-2	after 850	-> 1
U44-2	after 900	-> 1
U142-3	after 950	-> 1
U3-3	1000	-

Fig. 3: Temporal trends for versions

<i>Version</i>	<i>Date</i>	<i>Group</i>	<i>Comments</i>
it-ar	?	3	Near U25
it-b	?	2-3	Near vg
it-com	?	2-3	Near vg
it-z	?	3	Near M1739, it-b, geo-1
cop-sa	200	2	Between M81 and P46
cop-bo	300	3	Near M81 and M1739
cop-fay	325	?	Near cop-bo and cop-sa
vg	390	2-3	Near M81
arm	410	2-3	Near M81
geo-1	425	1-3	Between U150 and U18
syr-p	425	3	Near M1739
eth	500	3	Between U25 and M1739
it-d	500	3	Near U6
syr-pal	550	2-3	Resembles U150 and P46
geo-2	600	1	Between geo-1 and U18
syr-h	616	1	Near geo-2
slav	884	1	Near M1962

Fig. 4: Temporal trends for Church Fathers

<i>Father</i>	<i>Date</i>	<i>Group</i>	<i>Comments</i>
Clement (Alex.)	200	2	2:16:1
Origen	230	1-3	Nearest M1739, M1881, M104.
Eusebius	320	1-3	18:0:5. Four group 1 neighbours near 1-3 boundary.
Athanasius	350	1-3	7:0:2. Three group 1 neighbours near 1-3 boundary.
Cyril (Jer.)	350	3	Nearest TR, UBS4, U25. May be 1-2.
Didymus	350	2	0:16:4
Ephraem	360	1-3	12:5:6. Two group 1 neighbours near 1-3 boundary.
Ambrose	380	2-3	Nearest Attridge, Merk, Armenian.
Gregory (Nys.)	380	3	Similar location to Cyril (Jer.).
Chrysostom	390	1	
Jerome	390	2	2:10:4
Augustine	410	1	15:6:1
Cyril (Alex.)	430	2-3	Nearest U25 and M81.
Theodoret	430	1-3	Mixture of M1739 and U18?
Cassiodorus	550	3	1:0:6
Ps. Oecumenius	550	1-3	8:3:5. Three group 1 neighbours near 1-3 boundary.
John (Dam.)	730	1	
Theophylact	1090	1-3	Nearest Ethiopic, U25, M256.

Fig. 5: Group classification and place for Church Fathers

<i>Father</i>	<i>Date</i>	<i>Group</i>	<i>Place</i>
Clement (Alex.)	200	2	Alexandria
Origen	230	1-3	Caesarea and Alexandria
Eusebius	320	1-3	Caesarea
Athanasius	350	1-3	Alexandria
Cyril (Jer.)	350	3	Jerusalem
Didymus	350	2	Alexandria
Ephraem	360	1-3	Edessa
Ambrose	380	2-3	Milan
Gregory (Nys.)	380	3	Nyssa
Chrysostom	390	1	Antioch and Constantinople
Jerome	390	2	Bethlehem
Augustine	410	1	Hippo
Cyril (Alex.)	430	2-3	Alexandria
Theodoret	430	1-3	Cyrrhus
Cassiodorus	550	3	S. Italy
Ps. Oecumenius	550	1-3	Antioch?
John (Dam.)	730	1	Jerusalem
Theophylact	1090	1-3	Ohrid and Constantinople

References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *Novum Testamentum Graece*. Nestle-Aland, 27th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Aland, Kurt and Barbara. 1989. *The text of the New Testament: an introduction to the critical editions and to the theory and practice of modern textual criticism*. 2nd rev. and enlarged ed. Trans. Erroll F. Rhodes. Grand Rapids: Eerdmans.
- Brooks, James A. 1991. *The New Testament text of Gregory of Nyssa*. Society of Biblical Literature: the New Testament in the Greek Fathers, 2. Ed. Gordon D. Fee. Atlanta: Scholars Press.
- Chatfield, Christopher, and Alexander J. Collins. 1980. *Introduction to multivariate analysis*. London: Chapman and Hall.
- Epp, Eldon Jay. 1993b. 'The significance of the papyri for determining the nature of the New Testament text in the second century: a dynamic view of textual transmission'. In *Studies in the theory and method of New Testament textual criticism*. Ed. Eldon Jay Epp and Gordon D. Fee. Studies and documents, 45. Grand Rapids: Eerdmans, 274-297.
- Finney, T. J. 1997. 'Mapping the textual history of Hebrews'. *Revue informatique et statistique dans les sciences humaines* 33, 125-147.
- Harnack, Adolf. 1908. *The mission and expansion of Christianity in the first three centuries*. Vol. 2. *The spread of the Christian religion*. Theological translation library, 20. Trans. and ed. James Moffatt. 2nd enlarged and rev. ed. London: Williams and Norgate.

Heath, Dale Eldon. 1965. 'A transcription and description of Manuscript Vatican Greek 2061 (Gregory 048)'. Dissertation (PhD). Michigan State University.

Lake, Helen and Kirsopp. 1911. *Codex Sinaiticus Petropolitanus: the New Testament: the epistle of Barnabas and the Shepherd of Hermas*. Photographic facsimile with an introduction by Kirsopp Lake. Oxford: Clarendon Press.

Lake, Kirsopp. 1906. *The text of the New Testament*. Oxford church text books. 3rd ed. London: Rivingtons.

Metzger, Bruce M. 1977. *The early versions of the New Testament: their origin, transmission, and limitations*. Oxford: Clarendon Press.

Metzger, Bruce M. 1992. *The text of the New Testament: its transmission, corruption, and restoration*. 3rd enlarged ed. New York: Oxford University Press.

Milne, H. J. M. and T. C. Skeat. 1938. *Scribes and correctors of the Codex Sinaiticus*. Oxford: Oxford University Press.

Moulton, James Hope and Wilbert Francis Howard. 1928. *A grammar of New Testament Greek*. Vol. 2. *Accidence and word-formation with an appendix on Semitisms in the New Testament*. Edinburgh: T. & T. Clark.

Mullen, Roderic L. 1997. *The New Testament text of Cyril of Jerusalem*. Society of Biblical Literature: the New Testament in the Greek Fathers, 7. Ed. Bart D. Ehrman. Atlanta: Scholars Press.

Murphy, Harold S. 1959. 'On the text of codices H and 93'. *Journal of biblical literature* 78, 228-237.

The Oxford dictionary of the Christian Church. 1997. 3rd ed. Ed. F. L. Cross and E. A. Livingstone. Oxford: Oxford University Press.

- Panten, Kenneth E. 1995. 'A history of research on Codex Bezae, with special reference to the Acts of the Apostles: evaluation and future directions'. Dissertation (PhD). Murdoch University.
- Robertson, A. T. 1923. *A grammar of the Greek New Testament in the light of historical research*. 4th ed. Nashville: Broadman Press.
- Robinson, J. Armitage. 1895. *Euthaliana: studies of Euthalius, Codex H of the Pauline epistles, and the Armenian version*. Texts and studies, vol. 3, no. 3. Cambridge: Cambridge University Press. Repr. 1967. Nendeln: Kraus Reprint.
- Ropes, James Hardy. 1926. *The beginnings of Christianity*. Part 1. *The Acts of the Apostles*. Vol. 3. *The text of Acts*. Ed. F. J. Foakes Jackson and Kirsopp Lake. London: Macmillan. Repr. 1979. Grand Rapids: Baker Book House.
- Royse, James Ronald. 1981. 'Scribal habits in early Greek New Testament papyri'. Dissertation (ThD). Graduate Theological Union.
- Schick, Robert. 1998. 'Palestine in the early Islamic period: luxuriant legacy'. *Near Eastern archaeology* 61/2, 74-108.
- Skeat, T. C. 1984. 'The Codex Vaticanus in the fifteenth century'. *Journal of theological studies* 35/2, 454-465.
- Streeter, Burnett Hillman. 1925. *The four Gospels: a study of origins treating of the manuscript tradition, sources, authorship, & dates*. New York: Macmillan.
- Tischendorf, Konstantin von (ed.). 1862. *Bibliorum Codex Sinaiticus Petropolitanus*. Vol. 4. *Novum Testamentum cum Barnaba et Pastore*. Repr. 1969. Hildesheim: Georg Olms.
- Westcott, Brooke Foss and Fenton John Anthony Hort. 1881b. *The New Testament in the original Greek*. Vol. 2. *Introduction [and] Appendix*. Cambridge: Macmillan. Repr. 1974. Graz: Akademische Druck.

Zipf, George Kingsley. 1949. *Human behavior and the principle of least effort: an introduction to human ecology*. Repr. 1972, New York: Hafner.

Zuntz, GŸnther. 1945. *The ancestry of the Harklean New Testament*. British Academy supplemental papers, 7. London: Oxford University Press.

Zuntz, GŸnther. 1953. *The text of the epistles: a disquisition upon the corpus Paulinum*. Schweich Lectures of 1946. London: British Academy.

EVALUATION

Synopsis

Up until this point, the classical scaling technique has been assumed to be appropriate for the study of New Testament textual relations. The validity of my tentative classification scheme has also been taken for granted. This chapter presents an evaluation of classical scaling and my classification scheme.

As far as the classical scaling technique is concerned, the Euclidean assumption is tested and the effects of different data representations, different resemblance coefficients, different combinations of witnesses, and different combinations of units are compared.

Following this, the binomial theorem is used to develop confidence intervals for dissimilarities. An empirical approach is then applied to define probability ellipses that are the two-dimensional counterparts of confidence intervals. These provide a means of representing the effect of sampling errors on witness positions in the classical scaling maps.

A general survey of multivariate techniques applicable to classification is undertaken to provide a context for the evaluation of my classification scheme. Existing schemes such as quantitative analysis and group profile methods are evaluated at the same time.

Improvements to my collation method are suggested in the light of concepts developed through this evaluation and experience gained from production and analysis of the classical scaling maps. Ways of adapting existing collation results for multivariate analysis are also suggested.

Validity of the Euclidean assumption

Classical scaling assumes that dissimilarities behave as Euclidean distances (i.e., as distances between points in a plane). Fortunately, the method can still be valid in situations where this assumption is violated (Chatfield and Collins, 1980, 202):

It turns out that classical scaling is surprisingly robust to departures from Euclidean distance. Comparatively large random errors can be added to the Euclidean distances without seriously distorting the resulting configuration of points... Even if we take a monotonic function of the distances, we will probably still get a reasonable configuration.

There are methods of testing the Euclidean assumption. One indicator of non-Euclidean dissimilarities is the presence of negative numbers among the eigenvalues generated during classical scaling analysis. Here are the eigenvalues derived when the *SYN-TAX* software analyses the 'complete' sampled witness dissimilarity matrix:

EIGENVALUES				
1.41392	0.58324	0.45088	0.34768	0.22994
0.22221	0.20541	0.17578	0.17248	0.14087
0.11118	0.09795	0.07833	0.07403	0.06186
0.04942	0.04541	0.04042	0.03276	0.02968
0.02461	0.01865	0.01818	0.01475	0.01190
0.00787	0.00587	0.00511	0.00295	0.00000
0.00000				

The absence of negative eigenvalues indicates that the Euclidean assumption is valid, for this typical case at least.

Another test involves measuring the Euclidean distances between objects in a classical scaling map. These distances are then plotted against the actual dissimilarities from which the map was derived. If a curve fitted to the plotted points is linear and passes through the origin then the Euclidean assumption is justified (Chatfield and Collins, 1980, 204). Fig. 1 shows such a plot. The derived distances are calculated from the first and second classical scaling axis coordinates of the 'complete' primary witness textual maps (e.g., the first textual map of P46), while the actual dissimilarities are calculated from the corresponding data matrix using the simple matching coefficient.

As can be seen, the point cloud is quite linear. Whereas I have not calculated a line of best fit, it is apparent that such a line would not pass too far from the origin. It follows that the Euclidean assumption is justified for the primary witness data as well. Taken together with the robustness of classical scaling to variations from Euclidean geometry, it is reasonable to expect that classical scaling maps adequately reflect the actual configuration of the New Testament witnesses surveyed here.

Stability of the mapping technique

The maps found in this thesis result from a chain of procedures. Classical scaling maps are produced from dissimilarity matrices that are derived from binary data matrices using the simple matching coefficient. There is nothing to say that this is the best method of representing the textual, spelling, and other kinds of

variation under examination. The stability of the mapping technique will now be investigated by varying certain aspects of the sequence of processes. Only the first two axes of the 'complete' sampled witness maps will be used for the investigation. Significant anomalies should become apparent if investigation is restricted to these two axes alone because they are the most important ones. The 'complete' sampled witness maps are based on enough witnesses and units to be a suitable basis for the appraisal.

Fig. 2 serves as a reference map against which the effects of changes can be compared. It plots 26 sampled witnesses on the basis of 71 units. Five of the 31 witnesses that normally occur in the 'complete' sampled witness maps are not included. This permits direct comparison with a map derived from a multistate data matrix based on the UBS4 apparatus. The five excluded witnesses are not found in the UBS4 apparatus (i.e., U56, U142, U151, and M2815) or are not cited for each one of its variation units (i.e., P46).

Binary vs. multistate

Figs. 3 and 4 show maps derived from binary and multistate representations of the same basic data. It is necessary to use a resemblance measure that excludes double zeros if maps derived from binary and multistate data matrices are to be compared on an equal footing. For this reason, the corresponding dissimilarity matrices were generated using the Gower coefficient with double zeros excluded. (This coefficient counts matches. It is equivalent to the simple matching coefficient if double zeros are included, or to the Jaccard index if they are excluded, as in the present case.)

The two maps present a similar picture in the broad sense, but have important differences. Whereas M81 is closer to the group of editors' texts than U2 in the binary map, the opposite is true in the multistate map. Also, group 1 and group 3 texts tend to merge in the multistate map. This is cause for concern because the validity of the division between group 1 and group 3 texts is

called into question.

I attribute the discrepancy to differences in the respective dissimilarity matrices. These differences occur because the binary and multistate schemes employ disparate modes of comparison in places of variation, as will now be demonstrated. Consider four witnesses with distinct versions of a familiar sentence:

W1: The cat sat on the mat.

W2: The fat cat sat on the mat.

W3: The cat on the mat sat.

W4: The fat cat on the mat sat.

These texts can be represented with a binary data matrix based on a synthetic text:

	W1	W2	W3	W4
<i>The</i>	1	1	1	1
<i>fat</i>	0	1	0	1
<i>cat</i>	1	1	1	1
<i>sat</i>	1	1	0	0
<i>on</i>	1	1	1	1
<i>the</i>	1	1	1	1
<i>mat</i>	1	1	1	1
<i>sat</i>	0	0	1	1

The following units are left after removing ones that contribute nothing to a knowledge of relationships between witnesses:

	W1	W2	W3	W4
<i>fat</i>	0	1	0	1
<i>sat</i>	1	1	0	0
<i>sat</i>	0	0	1	1

This data matrix produces the following dissimilarity matrix if the Gower coefficient is employed with double zeros excluded:

W1	W2	W3	W4

W1	0.00			
W2	0.67	0.00		
W3	1.00	1.00	0.00	
W4	1.00	0.67	0.67	0.00

In a multistate representation, the readings might be divided into variation units as follows:

Variation unit 1:

state 1: cat sat	W1
state 2: fat cat sat	W2
state 3: cat	W3
state 4: fat cat	W4

Variation unit 2:

state 1: mat	W1, W2
state 2: mat sat	W3, W4

The corresponding dissimilarity matrix would be constructed by counting agreements alone:

	W1	W2	W3	W4
W1	0.00			
W2	0.00	0.00		
W3	1.00	1.00	0.00	
W4	1.00	1.00	0.00	0.00

As may be seen, these dissimilarities differ from those obtained in the binary representation. The difference is related to the manner in which the text is divided into variation units, and decreases as the multistate variation units approach the simple form of the binary units. In this example, equivalent results would have been obtained if the multistate variation units were chosen to be presence or absence of *fat*, *sat* (1st occurrence), and *sat* (2nd occurrence).

Further examples of the difference between binary and multistate representations can be observed by comparing maps I obtained in

a study based on multistate data (Finney, 1997) with the corresponding maps of this study. The question of which is the better representation is not straightforward and may well become a subject of controversy in the future. On one hand, the multistate representation is more compact and conforms to the division of variation units into readings found in a critical edition. On the other hand, the binary representation is absolute, not being affected by differences of opinion concerning how a variation unit should best be divided into readings. It also allows greater precision in determining the extent of agreement between two witnesses, as is apparent from the example just given.

Smilarity coefficient

The effects of using different resemblance measures are generally quite small. As the Gower coefficient with double zeros excluded is equivalent to the Jaccard index, a comparison of figs. 2 and 3 shows the effect of changing the resemblance measure from the simple matching coefficient to the Jaccard index. Apart from an increase in dispersion, the relative positions of the witnesses do not change very much. The same maps show the effect of excluding double zeros from consideration. As there are many double zeros in the data matrices, their exclusion tends to reduce the frequency of agreement between related witnesses. As a result, the witnesses cluster less tightly.

The map shown in fig. 5 was produced using the Russell and Rao index. It confirms that this index can be regarded as a compromise between the simple matching coefficient and the Jaccard index. A significant weakness of the Russell and Rao index is that relatively small proportions of variation are explained by the first two axes when it is used. In the present case, the percentages are only 9% and 6%, compared with 29% and 15% for the simple matching coefficient.

Fig. 6 shows that using the Euclidean distance to measure resemblance produces a map that is virtually identical to the one produced with the simple matching coefficient, except for a change of scale. This is to be expected as the two measure are

closely related (Podani, 1994, 34).

Dependence on objects

The dependence of the maps on the number of witnesses can be investigated by progressively removing witnesses and comparing resultant maps with the reference map containing a full complement of witnesses. Fig. 7 is a plot of every second witness found in the reference map, fig. 2. In the same way, fig. 8 plots every second witness of fig. 7, and fig. 9 plots every second witness of fig. 8. The percentages of variation explained by the two mapped dimensions increase as less witnesses are plotted. This is because a two-dimensional picture becomes a more adequate representation as the number of objects decreases.

Figs. 2 and 7 appear different at first sight. The contrast is mainly due to a reflection relative to the second axis and the removal of two outliers, being U6 and Kilpatrick's text. With the exception of M365, the remaining witnesses of fig 7. have substantially the same relative positions as found in the reference map. Similarly, the relative positions of remaining witnesses do not exhibit significant changes as more witnesses are removed in figs. 8 and 9. This demonstrates that the maps give a basically invariant configuration regardless of the particular combination of witnesses selected for plotting. That is, witness positions are not usually sensitive to the inclusion or exclusion of other witnesses, making the classical scaling technique well suited to a sampling approach. Even so, the plotted position of a witness may be sensitive to the presence or absence of particular witnesses, as is the case for M365.

Dependence on variables

A progressive removal technique can also be applied to examine the effects of reducing the number of units upon which a classical scaling map is based. Figs. 10 to 13 plot maps of the same witnesses on the basis of decreasing numbers of units. Fig. 10 results from considering every second unit of the reference map, fig. 2. In the same way, fig. 11 is based on every second unit of fig. 10, and so on, with alternate units being removed from

consideration. This time, the percentages of variation explained are relatively constant because the same number of witnesses is being plotted.

Witnesses tend to occupy coincident positions more frequently and become displaced relative to their positions in the reference map as the number of units decreases. Essentially, the uncertainty of each witness position increases as the number of units from which it is calculated decreases. In this example, the map based on eighteen units (fig. 11) is still a reasonably good representation of the reference map, but the representations quickly degrade in the next two cycles of removal. The extent of degradation can be quantified by means of statistical theory, as will be discussed under the heading of confidence intervals.

Block mixture

Rather than removing every second unit, an entire block of consecutive units can be removed. The map of fig. 14 is based on the first 36 of the 71 reference map units. Comparison of the two maps shows that once a reflection and a more uniform dispersion relative to the second axis is taken into account, the witnesses do not have greatly contrasting relative positions in the two maps, with the exceptions of U6 and M1739. If any significant differences are apparent from this kind of examination, they can be attributed to the phenomenon of block mixture, where adjacent parts of the same manuscript are affiliated with differing textual groups.

Depending on the limits of certainty set by the number of units available for examination, smaller sections of text can be mapped, as in fig. 15. Witnesses affected by block mixture manifest a shift in relative position (e.g., U150) while witnesses with a uniform text preserve a stable configuration. The minimum size of sections to be compared is determined by the minimum number of units required for confidence that a genuine difference in relative positions exists.

Other means can be used to select blocks of text for the purpose

of identifying witnesses affected by block mixture. The data matrix generation procedure employed in this thesis includes all witnesses that exist for the same units as a fragmentary witness. A witness affected by block mixture can therefore be isolated by comparing its position relative to other witnesses in a number of different principal maps. For example, the position of P46 relative to neighbours such as U2 and U6 differs between its own principal maps and those of P13. This suggests that the textual affiliation of P46 differs between those sections of Hebrews for which P13 exists and the rest of Hebrews.

Confidence intervals

Mapped witness positions are determined by the mutual dissimilarities of the witnesses. Each dissimilarity is subject to random errors that tend to increase as the number of units from which the dissimilarity is calculated decreases. A statistical analysis allows confidence intervals to be defined so that the significance of a dissimilarity or a distance between two witnesses in a classical scaling map can be assessed.

Dissimilarities of unrelated witnesses: binary case

The dissimilarities of unrelated binary witnesses span a range of values due to random fluctuations. To demonstrate that this is so, a dissimilarity matrix will now be derived from a data matrix consisting of randomly selected 'ones' and 'zeros'. Fig. 16 represents such a data matrix. It contains ten pseudo-witnesses of thirty units in which each entry is a 'one' or 'zero' obtained from a random number generation program. Fig. 17 is the corresponding dissimilarity matrix obtained with the simple matching coefficient. Taking the first two pseudo-witnesses as an example, there are matching 'ones' and 'zeros' in twelve out of thirty units. This implies that the simple matching coefficient is $12/30$ (i.e., 0.40). The corresponding dissimilarity is the complement of this value: $1 - 0.40 = 0.60$.

Fig. 18 plots the pseudo-witnesses in a classical scaling map. It is somewhat disconcerting to observe that this map looks similar to

the one obtained for 'complete' primary witnesses. It is necessary to know the expected range of dissimilarities for unrelated witnesses in order to distinguish between a map that represents nothing more than a random distribution of points and a map in which relative witness positions are due to genuine relationships. The distribution of dissimilarities for the random pseudo-witnesses is plotted in the histogram of fig. 19. The interval labelled 'a' includes dissimilarities from 0.00 up to 0.05, interval 'b' goes from 0.05 up to 0.10, and so the intervals continue until 'o', which spans 0.70 up to 0.75. The boundary between intervals 'j' and 'k' corresponds to a dissimilarity of 0.50.

Dissimilarities of unrelated binary witnesses conform to a particular statistical distribution. Consider an experiment that consists of repeatedly conducting some trial that can have only two outcomes, either success or failure. If the trials are independent (i.e., each trial has the same probability of success, regardless of the outcomes of the other trials) then they are known as Bernoulli trials (Spiegel, 1982, 108). The outcomes of a series of Bernoulli trials obey the binomial distribution with mean np and standard deviation $\sqrt{npq}$, where p is the probability of success, $q = 1 - p$ is the probability of failure, and n is the number of trials. The proportion of successes also obeys the binomial distribution with mean p and standard deviation $\sqrt{pq/n}$. It turns out that the normal distribution is a reasonably good approximation to the binomial distribution provided that $np > 10$ and $nq > 10$ (Moore and McCabe, 1993, 380-1).

This result can be applied to find a confidence interval for the simple matching coefficient of two unrelated witnesses. The columns of a binary data matrix are binary representations of witnesses. In the nomenclature of linear algebra, each column of a data matrix constitutes a column vector. That is, each witness is represented by a column vector. A random binary column vector of length n can be constructed by randomly selecting n 'ones' and 'zeros'. Such a construction will be called a random vector from now on. By definition, members of a set of random vectors are unrelated.

Taking any two random vectors, the probability that binary digits in corresponding positions will coincide can be calculated if the expected frequencies of 'ones' and 'zeros' are known. Coincidence occurs if both digits are 'one' or both are 'zero'. The anti-coincident outcomes are 'one' then 'zero' or 'zero' then 'one'. These four outcomes are the only ones possible, and have the following probabilities:

$$P\{1,1\} = P\{1\} \times P\{1\}$$

$$P\{0,0\} = P\{0\} \times P\{0\}$$

$$P\{1,0\} = P\{1\} \times P\{0\}$$

$$P\{0,1\} = P\{0\} \times P\{1\}$$

The comparison of corresponding entries in two random vectors of length n is equivalent to a series of n Bernoulli trials. If success is regarded as coincidence of corresponding entries then the probability of success is:

$$p = P\{1,1\} + P\{0,0\}$$

If two random vectors represent two unrelated witnesses of n units each then their simple matching coefficient corresponds to the proportion of successes and will obey the binomial distribution, have a mean value of p , and a standard deviation of $\sqrt{pq/n}$.

The normal distribution is a reasonably good approximation to the binomial distribution provided that $np > 10$ and $nq > 10$. (For $p \sim 0.5$, these conditions are satisfied if $n > 20$.) A normally distributed random variable will fall within 1.96 standard deviations of the mean in 95% of cases. As a result, a 95% confidence interval for the simple matching coefficient of two unrelated witnesses spans 1.96 standard deviations either side of p . The dissimilarity of two witnesses is the complement of their similarity coefficient, so the expected mean value of the dissimilarity is $1 - p = q$. Given that the normal approximation holds, it follows that the 95% confidence interval for a

dissimilarity of two unrelated witnesses calculated with the simple matching coefficient is:

$$q - 1.96 \times \sqrt{pq/n} < \text{dissimilarity} < q + 1.96 \times \sqrt{pq/n}$$

For the demonstration given before, $p = q = 0.5$, and $n = 30$. The corresponding 95% confidence interval is:

$$0.32 < \text{dissimilarity} < 0.68$$

As expected, nearly all of the random dissimilarities lie in this range.

The hypothesis of no relationship cannot be rejected if a pair of witnesses have a dissimilarity inside this interval. Conversely, the hypothesis of no relationship cannot be accepted for a pair of witnesses whose dissimilarity is outside the interval. That is, significantly small and significantly large dissimilarities both indicate relationship between witnesses.

It makes sense that two witnesses with a significantly small dissimilarity (i.e., 'distance') should be regarded as related. However, the fact that a significantly large dissimilarity can also indicate relationship is somewhat counter-intuitive. Such a large value implies that the number of disagreements between the witnesses is too great to be explained by a hypothesis of no relationship. This would occur if a scribe shunned the readings of a particular manuscript and only copied readings from exemplars that did not agree with it. A witness related to the scribe's copy and one related to the suspect manuscript would then disagree more often than would be expected if the two were not related. From now on, two witnesses with a significantly large dissimilarity will be described as having an opposite relationship.

The foregoing analysis makes certain assumptions concerning the units of unrelated witnesses. Firstly, each unit is treated as having the same probability of being 'one' or 'zero'. This is not true of real witnesses as some units are far more likely to contain a 'one'

than a 'zero', and the opposite is true of other units. The binomial distribution is not a valid description of coincidence between the units of unrelated witnesses unless their units have a substantially constant probability of being a 'one' or 'zero'. For the present purposes, I will assume that this condition is satisfied. Further study of the validity of this assumption is required before the following results can be regarded as established.

Secondly, each unit is treated as independent of any other. This condition is not satisfied for the binary textual variation data matrices employed here because an alteration to one word is often accompanied by an alteration to a nearby word or words, with the result that consecutive units tend to be associated. For this reason, the interval just obtained is only a first approximation to the expected amount of variation. It represents an under-estimate because correlation implies a smaller effective number of independent units and this, in turn, implies a greater dispersion about the mean.

Compensation for a lack of independence can be made by reducing the effective number of units. The deviation from the mean that defines the interval will then be of the form $z\sqrt{pq/cn}$, where c is a constant that is less than one if the units are not independent, and z is the number of standard deviations corresponding to the chosen confidence level. A value for c that applies to my binary data matrices can be estimated by comparing the numbers of units in the binary and multistate representations of the 'complete' sampled witnesses, which are 71 and 43, respectively. If it is reasonable to assume that the reading of a given variation unit in the UBS4 apparatus does not depend on the reading of any other variation unit then the 43 variation units can be regarded as independent. That is, the 71 units of the binary representation have an effective value of 43, implying that c is $43/71$ (i.e., 0.61). With this value, the following 95% confidence interval gives the expected dispersion of dissimilarities for unrelated witnesses in this study:

$$q - 1.96 \times \sqrt{pq} / 0.61 \times n < \text{dissimilarity} < q + 1.96 \times \sqrt{pq} / 0.61 \times n$$

n

Confidence intervals can now be calculated for actual dissimilarities. The 'complete' primary witness data matrices consist of twelve witnesses of 728 units each. Each matrix contains a proportion of 4487/8736 (i.e., 0.514) 'ones' and 4249/8736 (i.e., 0.486) 'zeros', where 8736 (i.e., 12 x 728) is the total number of 'ones' and 'zeros'. Hence, the probability of a match between corresponding entries in unrelated witnesses is estimated to be $0.514^2 + 0.486^2$ (i.e., 0.50). With $p = 0.50$ and $q = 1 - 0.50 = 0.50$, the deviation about the mean is:

$$1.96 \times \sqrt{0.50 \times 0.50 / 0.61 \times 728} = 0.05 \text{ (approx.)}$$

That is, the 95% confidence interval for dissimilarities among witnesses of 728 units is:

$$0.45 < \text{dissimilarity} < 0.55$$

Inspection of the 'complete' primary witness dissimilarity matrices show that a number of dissimilarities exceed the upper boundary of this interval. This implies either that the corresponding witnesses are oppositely related or that the estimate of c is incorrect. In the event that the second option is true, another value for c can be estimated by assuming that the largest dissimilarity is for unrelated witnesses and coincides with the upper boundary of the 95% confidence interval:

$$1.96 \times \sqrt{0.50 \times 0.50 / c \times 728} = 0.63 - 0.50 = 0.13$$

This implies that $c = 0.078$.

These two estimates of c are very different. It is possible that the distribution of dissimilarities in real dissimilarity matrices will provide some guidance as to the more appropriate value. Each 'complete' primary witness dissimilarity matrix has 66 dissimilarities (i.e., 12 x 11 / 2). Fig. 20 shows the distribution of dissimilarities for these witnesses.

This distribution can be regarded as two superimposed distributions, the first corresponding to related witnesses and the second to unrelated witnesses. The second distribution is centred on 0.50. Given that it is a binomial distribution, it should be bell-shaped; however, its width is not known. If c is 0.61, nearly all of the corresponding dissimilarities should lie in the range $0.45 < \text{dissimilarity} < 0.55$. The range is $0.37 < \text{dissimilarity} < 0.63$ for $c = 0.078$. If the first distribution quickly drops to zero after its peak then the second distribution is better described by the broader range. If, on the other hand, the first distribution levels out after its peak, the narrower range is more appropriate. Neither range for the second distribution can be ruled out because the shape of the first distribution is not known.

At this point it is helpful to look at the distribution of dissimilarities among the sampled witnesses. Each 'complete' sampled witness dissimilarity matrix contains 465 dissimilarities (i.e., $31 \times 30 / 2$). Fig. 21 gives the distribution of dissimilarities using the same intervals as before. Given that the distribution of unrelated witnesses is symmetrical about a mean value of 0.5 and that the distribution of related witnesses falls off in a uniform fashion after its peak, the interval from 0.55 to 0.60 has more dissimilarities than expected. This implies that there are some oppositely related witnesses, which, in turn, implies that the second estimate of c (0.078) is based on a false assumption.

The larger than expected number of dissimilarities in the interval from 0.55 to 0.60 may represent a random fluctuation, in which case we are still unable to choose the better estimate. Even so, I will proceed on the assumption that c is 0.61. All dissimilarities that exceed 0.55 among the sampled witnesses relate to U6 or Kilpatrick's text. In the primary witnesses, dissimilarities of more than 0.55 always involve U6, U56, or its close neighbour U142. It is not beyond the realms of possibility that manuscripts such as U56 and U142 preserve a text that actively shuns non-Byzantine texts, or that many manuscripts should avoid readings found in U6. Therefore, it is not unreasonable to assume that

dissimilarities involving these witnesses will have the significantly large values that correspond to an opposite relationship.

Confidence intervals for some frequently used sample sizes will now be calculated using this value of c . Each 'complete' sampled witness dissimilarity matrix contains 31 witnesses of 71 units each. There are proportions of 947/2201 (i.e., 0.430) 'ones' and 1254/2201 (i.e., 0.570) 'zeros'. This leads to an estimate of $p = 0.430^2 + 0.570^2 = 0.51$ and $q = 1 - 0.51 = 0.49$. The resultant deviation about the mean is:

$$1.96 \times \sqrt{0.51 \times 0.49 / 0.61 \times 71} = 0.149$$

Therefore, the 95% confidence interval for dissimilarities among unrelated witnesses with 71 units is:

$$0.34 < \text{dissimilarity} < 0.64$$

It follows that any two 'complete' sampled witnesses with a dissimilarity of less than 0.34 are related. Confidence limits can be worked out in this manner for any dissimilarities calculated from more than twenty units.

I have made five units the minimum number required for a map. Also, some of the map interpretation procedures of the foregoing chapters make a distinction between maps with fifteen or more units and those with less. It is therefore desirable to have confidence limits for dissimilarities based on five and fifteen units as well. The normal approximation to the binomial distribution is no longer valid for such small numbers of units, so exact calculations are required.

According to the binomial distribution, if the probability of agreement is 0.5 then the probability of five agreements in five trials is $1/32$ (i.e., 0.031). As $1/32$ is less than 5%, the hypothesis of no relationship can still be ruled out at a level of 95% confidence given complete agreement in five units. Under the

same conditions, the probability of four agreements in four trials is $1/16$ (i.e., 0.062). This is greater than 5%, so the hypothesis of no relationship cannot be ruled out no matter what the number of agreements. The same goes for any number of units less than four.

This calculation does not take account of the correlation between units that is likely to occur in the textual data matrices of this study. In order to compensate for the lack of independence, the minimum number of units required for significant agreement would be $5 / 0.61$, which is about eight. As a result, witnesses occupying the same location in textual maps of only five units have less than a 95% chance of being substantially the same.

For witnesses of fifteen units, the 95% confidence interval extends from four to eleven out of fifteen agreements for independent trials where the probability of agreement is 0.5. This corresponds to dissimilarities of:

$$0.27 < \text{dissimilarity} < 0.73$$

The normal approximation gives a deviation of:

$$1.96 \times \sqrt{0.50 \times 0.50 / 15} = 0.25$$

The corresponding interval is:

$$0.25 < \text{dissimilarity} < 0.75$$

This compares quite well with the confidence interval obtained by exact methods. Once compensation is made for the lack of independence, the deviation is:

$$1.96 \times \sqrt{0.50 \times 0.50 / 0.61 \times 15} = 0.32$$

which corresponds to an interval of:

$$0.18 < \text{dissimilarity} < 0.82$$

That is, two witnesses of fifteen units can only be regarded as related if their dissimilarity is less than 0.18 or more than 0.82.

Dissimilarities of unrelated witnesses: multistate case

Multistate data matrices can have more than two readings per variation unit. Most of the variation units in the UBS4 apparatus have only two readings, but others have more. This table, which relates to the UBS4 apparatus for Hebrews, shows the numbers of variation units with respective numbers of readings:

<i>No. of readings</i>	2	3	4	5	6	7+
<i>No. of var. units</i>	22	11	5	3	2	0

For simplicity, I will treat each reading of a variation unit as equally probable. This is seldom true in reality, so the validity of what follows depends upon whether the distribution of dissimilarities is seriously affected by unequal probabilities of readings. (Unfortunately, my statistical abilities are not sufficient to provide an answer to this question.) I will also assume that variation units are independent, so that the reading of one variation unit does not depend on the reading of any other variation unit.

The multistate variation units can be arranged into groups with the same numbers of variation units. The distribution of coincident readings for unrelated witnesses can then be treated as a binomial distribution on a group by group basis. Once the mean value of coincidence and its standard deviation are calculated for each group, figures can be calculated for all of the groups combined.

Under the assumption of equal probabilities, the expected proportion of coincidence among unrelated witnesses, p_i , for each group of variation units is the inverse of the number of readings in each group member. According to the binomial distribution, the corresponding variance (i.e., square of the standard deviation) is $p_i q_i / n_i$, where $q_i = 1 - p_i$ and n_i is the

number of variation units in the group:

<i>Index (i)</i>	1	2	3	4	5	6+
<i>No. of readings</i>	2	3	4	5	6	7+
n_i	22	11	5	3	2	0
p_i	1/2	1/3	1/4	1/5	1/6	-
$p_i q_i / n_i$	0.011	0.020	0.038	0.053	0.069	-

The overall expected proportion of coincidence is the weighted average of the group proportions:

$$\sum n_i p_i / \sum n_i = 0.39$$

The overall variance is calculated using a formula appropriate to the weighted mean (Bevington, 1969, 60):

$$\sum n_i p_i q_i / (\sum n_i)^2 = 0.0050$$

The deviation about the mean for a 95% confidence interval is then:

$$1.96 \times \sqrt{0.0050} = 0.14$$

The Jaccard index is the appropriate resemblance measure for multistate data. It is the ratio of agreements to the total number of variation units compared. As such, it is equivalent to the overall proportion of coincidence just calculated. Apart from a factor of one hundred, it corresponds to the percentage agreement measure popular among New Testament textual researchers. Turning to the dissimilarity matrix of witnesses represented by multistate data, the dissimilarity of two witnesses is the complement of their Jaccard index. In the case of unrelated witnesses, the standard deviation of their dissimilarities is the same as the standard deviation of their overall proportion of agreement. As the complement of the overall proportion of agreement is 0.61, and 1.96 standard deviations is 0.14, the 95% confidence interval for dissimilarities among unrelated multistate witnesses represented by the UBS4 apparatus of Hebrews is:

$$0.47 < \text{dissimilarity} < 0.75$$

Hence, we can be 95% confident that any two of these witnesses with a dissimilarity of less than 0.47 (i.e., a percentage agreement greater than 53%) are related.

Fig. 22 shows the distribution of dissimilarities in a multistate representation of the 'complete' sampled witnesses, with U56, U142, U151, M2815, and P46 excluded. The upper boundary of the 95% confidence interval just given coincides with the largest dissimilarity. The dissimilarities reach higher values than dissimilarities derived from a binary representation. This is consistent with the larger mean value of dissimilarities for unrelated witnesses predicted in the foregoing analysis.

Probability ellipses for witness locations

The confidence intervals developed so far concern the dissimilarities of unrelated witnesses. It would be useful to have confidence intervals for witness locations as well. The locations of witnesses within maps are affected by random fluctuations in the dissimilarities between pairs of witnesses. In a multidimensional representation with equal axis scales, these confidence intervals would be represented by hyperspheres. In a two-dimensional map of unequal axis scales, the interval would be represented by an ellipse. Such an ellipse that is characterised by a particular confidence level will be called a probability ellipse here.

It may be possible to define probability ellipses based on an analysis from first principles of the kind just used to define dissimilarity intervals. My statistical abilities are too meagre to undertake this kind of analysis, so I will settle for an empirical approach based on the increase of deviations from expected values that is observed as sample sizes decrease.

The location of a witness in a classical scaling map is determined by its dissimilarities to every other witness in the map. Each one

of these dissimilarities is affected by random fluctuations of the kind that produce a range of dissimilarity values among unrelated witnesses. Therefore, the location is subject to random fluctuations as well. The standard deviation of a sample mean varies as $1/\sqrt{n}$ (Moore and McCabe, 1993, 395). Assuming that random fluctuations of a map location behave in the same manner as random fluctuations in a sample mean, the deviation of a map coordinate in each axis also varies as $1/\sqrt{n}$. That is,

$$\text{coordinate deviation} = k/\sqrt{n}$$

where k is a proportionality constant.

The data matrices employed to examine the behaviour of map location versus sample size for 26 of the 'complete' sampled witnesses provide the data necessary to estimate a value for k . Taking the positions of witnesses in the map based on 71 units as reference values, deviations can be calculated for each witness in the 36-, 18-, 9-, and 5- unit maps derived by discarding every second unit. Deviations are calculated for each of the two dimensions, separately. A quantity that is analogous to the standard deviation can be calculated for the two axes of each map using the formula:

$$\text{coordinate deviation} = \sqrt{\sum (x_i - r_i)^2 / (n - 1)}$$

In this case, x_i is the coordinate of a witness in one of the derived maps and n is the number of witnesses, which is 26. Whereas the standard deviation calculates deviation relative to the mean, this form measures deviation relative to the corresponding reference coordinate in the dimension being examined, r_i . A value of $n - 1$ is used for the degrees of freedom by analogy with the unbiased estimate of the standard deviation, which also uses $n - 1$. The deviations calculated according to this formula are:

	36	18	9	5
Axis 1	0.058	0.096	0.155	0.145
Axis 2	0.058	0.105	0.150	0.215

<i>Mean</i>	0.058	0.100	0.153	0.180
<i>k</i>	0.348	0.426	0.458	0.403

Both axes appear to have approximately equal deviations. The anomaly between figures for the map based on five units may well be due to the small sample size. Assuming that the deviations are the same in both axes, their average values provide a better estimate of the true values. The last row gives estimates of k obtained from the average deviations using the following equation:

$$k = \text{deviation} \times \sqrt{n}$$

The estimates for k are approximately equal, which lends credence to the assumption that map locations fluctuate in the same way as sample means. Using the square root of the number of units in each map as a weight, the weighted mean of the estimates of k is 0.40. Therefore, the radius of the probability ellipse in each dimension is estimated to be:

$$\text{radius} = z \times 0.40 / \sqrt{n}$$

where z is the number of standard deviations corresponding to the confidence level and n is the number of units. For a 95% confidence level, z is 1.96 and the estimate becomes:

$$\text{radius} = 0.78 / \sqrt{n}$$

If sample sizes of less than 30 units are considered, the z value should be replaced with the appropriate t distribution critical value. For a confidence level of 95%, the value is 2.78 for five units, and 2.14 for fifteen units. (The number of degrees of freedom specified in a table of t distribution critical values corresponds to the number of units minus one.)

The following table gives values for the radius of a 95% probability ellipse versus the number of units from which a map is derived. The radius along all of the axes is assumed to be

equal, in accordance with the similarity of deviations along the first two axes that was observed before.

<i>Number of units</i>	5	8	15	30	71	728
<i>Radius of ellipse</i>	0.50	0.33	0.22	0.14	0.09	0.03

Probability ellipses provide a means of appreciating the uncertainty in a mapped witness location. If a probability ellipse is centred on the coordinates of a mapped witness then the probability that the true coordinates of the witness lie within the area defined by the ellipse is equal to the confidence level. For a given confidence level, it is only possible to say that two witnesses differ if their respective probability ellipses do not overlap. Consequently, the minimum separation required for two witnesses to be considered different is the sum of the radii of their ellipses. As each witness of a map is based on the same number of units in this study, the probability ellipse of each witness in a map has the same radius. The minimum separation required for witnesses to be considered different is therefore twice the relevant radius.

Considering the reference map of fig. 2, the 95% probability ellipse of each witness has a radius of 0.09 axis units because the map is derived from 71 units. Imagining that an ellipse of this size is centred on the map coordinates of each witness, it is possible to say which witnesses are significantly different from other witnesses. It follows that witnesses such as U6 and Kilpatrick are significantly different from all other witnesses. There is also a significant difference between witnesses such as UBS4 and M81, or U2 and TR. The witnesses may be divided into groups by reference to their first axis coordinates as follows:

<i>Group</i>	<i>Members</i>	<i>Range</i>	<i>Centre</i>
1	M2127 - M365	0.22 - 0.30	0.26
2	NA25 - Von Soden	-0.28 - -0.10	-0.19
3	M81 - U25	-0.02 - 0.18	0.08

These groups correspond to the ones discussed in the last chapter.

The distances between the centres of adjacent groups are just sufficient for us to be 95% confident that the groups differ, even though individual members of one group may not differ significantly from members of the next group.

As the number of units upon which a map is based decreases, the uncertainty of the witness locations increases and the probability ellipses expand accordingly. The 95% probability ellipses for five units have a radius of 0.50 axis units. As no two witnesses ever have a separation of more than 1.0 axis units (i.e., 2×0.50), no two witnesses in a five unit map can be considered to be different at a 95% confidence level. Mapped witness coordinates usually exhibit a range of about 0.7 axis units in both the first and second dimensions. Half of this range is 0.35 axis units, which is just greater than the 0.33 axis units radius of a 95% probability ellipse for eight units. That is, the maps of this study must be based on at least eight units before any practically obtained distance between mapped witnesses can be considered significant. This is consistent with the minimum of eight units required for significant agreement that was obtained previously by considering binomial probabilities.

Classification

In the preceding chapter, I divided witnesses into three broad categories as a tentative first step towards classification. Multivariate analysis provides a useful perspective from which this and other classification schemes can be evaluated. Techniques such as classical scaling, principal component, correspondence, and canonical variates analysis represent optimum solutions, making them superior to the *ad hoc* classification methods presently employed by New Testament textual researchers.

Classification aims to group objects into a number of clusters. The term 'cluster analysis' is virtually synonymous with 'classification' in the parlance of multivariate statistics. Chatfield and Collins (1980, 212) write,

cluster analysis aims to allocate a set of individuals to a set of mutually exclusive, exhaustive, groups such that individuals within a group are similar to one another while individuals in different groups are dissimilar. This set of groups is usually called a *partition*.

They commend visual inspection of a scatter diagram (i.e., a two-dimensional plot of coordinates that represent objects) as an effective means of finding a partition (1980, 229). This is the method I used to identify groups in the last chapter. More analytical approaches are available but they should be used with caution since they share inherent weaknesses: there is no universally accepted definition of a cluster; different methods acting on the same data can produce different partitions; a method will find a partition even if there is no natural grouping; and more than one meaningful classification can apply to a set of data, depending on the investigator's purpose (Chatfield and Collins, 1980, 215-6).

Mindful of these reservations, a number of multivariate classification techniques are demonstrated below. As they are founded on purely mathematical procedures, it is reasonable to expect that their partitions are as effective or better than those of existing classification schemes. All of the demonstrations make use of Dr János Podani's *SYN-TAX 5* software.

Hierarchical trees

Hierarchical clustering produces a tree diagram or dendrogram that consists of a 'nested sequence of partitions' (Chatfield and Collins, 1980, 219). Figs. 23 to 26 show tree diagrams constructed using single-link clustering and the simple matching coefficient to measure resemblance. The diagrams are inverted with the result that the 'trunk' is towards the top and the 'branches' are towards the bottom.

Single-link clustering is one of many available methods. It works by progressively linking closest objects or groups of objects,

where the 'distance' between two groups is defined as the minimum dissimilarity between an object in one group and an object in the other. There are good reasons for preferring single-link clustering to other methods, although it suffers from a 'chaining' effect whereby distinct clusters can be prematurely linked due to intermediate objects (Chatfield and Collins, 1980, 227-8).

Fig. 23 relates to the random binary witnesses. The minimum dissimilarity is 0.37 for witnesses '2' and '5'. As can be seen, the lowest link joins these two witnesses at the appropriate place on the adjacent scale. The next lowest link joins witnesses '1', '3', '4', and '7' to the group made up of witnesses '2' and '5'. This is because witnesses '1' and '3', '2' and '3', '3' and '4', and '5' and '7' all share dissimilarities of 0.40. A distinctive feature of this tree diagram is the large minimum dissimilarity which is to be expected of unrelated witnesses.

Fig. 24 goes some way towards justifying my tentative partition. If the tree is 'chopped' at a dissimilarity just exceeding the dissimilarity at which U25 and U150 are linked (i.e., ~ 0.31), the following partition results:

M2815 TR U151 U18 U142 U56 | P46 U2 UBS4 | U150 U25 |
U6

Apart from U6 not being included with P46, U2, and UBS4, this is the same as my partition.

Unfortunately, the partition shown in fig. 24 is not entirely stable. A tree diagram derived from the dissimilarity matrix that was used to construct the textual maps of U3 (i.e., Codex Vaticanus) is shown in fig. 25. If this tree is chopped at a level just above where U56 and U142 link to witnesses such as M2815 and TR then the first two groups of my partition are preserved. However, the third group, comprising U25 and U150, fragments.

A similar condition prevails for my partition of sampled

witnesses. Recall that for the purposes of analysing the classical scaling map results, I divided sampled witness maps into three regions corresponding to those found in the primary witness maps. As a result, sampled witnesses were partitioned according to their coordinate in the first map dimension, with the positions of M2127 and M81 serving to define boundary lines that divide group 1 from group 3, and group 2 from group 3, respectively (cf. fig. 2).

This partition does not appear to be in good agreement with the one suggested by the sampled witness tree diagram of fig. 26. Witnesses such as M104, M256, and M1881 should be grouped with U25 and M1739 rather than with witnesses such as U18 and the *Textus Receptus*. Also, U150 should not be grouped with U25, a conclusion supported by the tree diagram of fig. 25.

These discrepancies can be remedied by changing the group boundaries from crisp boundaries to transition zones. Witnesses with a first axis coordinate near a transition zone should be considered as possibly belonging to either of the respective groups, with a decision being reserved until further information (in the form of a dissimilarity matrix with more witnesses or units or both) becomes available. Fortunately, this change has virtually no effect on the discussion of results in chapter 7. This is because sampled witnesses near a transition zone are already classified as possibly belonging to either of the respective groups. (For example, the Armenian version is classified as group 2-3.)

The concept of 'fuzzy' group boundaries is consistent with the existence of uncertainties in dissimilarities resulting from sampling errors. Uncertainties decrease as the number of units upon which the dissimilarity matrix is based increases. Some witnesses can migrate to a different group if a different number of units are considered because slight changes in dissimilarities can result in a rearrangement of the hierarchical tree.

This instability in classification would be avoided if the

dispersion among groups was relatively large with respect to the dispersion between group members. Using variance as a measure of dispersion, well defined grouping would be associated with a relatively large ratio of among group variance to within group variance. A corresponding tree diagram would be the antithesis of that found in fig. 23: its objects would link at relatively low dissimilarity levels, while groups of linked objects would not join until relatively high dissimilarity levels.

Tree diagrams for the primary and sampled witnesses of Hebrews do not conform to the pattern expected of unrelated witnesses or well defined groups of witnesses. Instead, the witnesses divide into groups over a range of dissimilarity levels so that some groups are compact while others are diffuse. There is no obvious dissimilarity level at which to chop either the primary or sampled witness trees. That is, there is no obvious number of groups in either hierarchy.

This is an important observation, especially since there is a tendency for New Testament textual researchers to divide witnesses into three or four groups, depending on whether the Caesarean text is considered to exist. With group division taking place over a range of dissimilarity levels, there is nothing to stop witnesses being partitioned into any convenient number of groups. By the same token, there is no reason to prefer one number of groups over another within the bounds set by the number of witnesses and units.

It is always possible that this situation will change if more comprehensive data matrices are considered. Including more witnesses may increase the number of well defined groups, while the analysis of more units could increase the ratio of among groups to within groups dispersion. In general, the safest classification is the one based on the maximum possible number of units because uncertainties are then least in a relative sense. With regard to the tree diagrams, links within the 95% confidence interval for dissimilarities of unrelated witnesses cannot be regarded as significant. The lower interval boundary is

0.45 for the primary witnesses and 0.34 for the sampled witnesses. Links at dissimilarity levels *below* these boundaries represent real grouping.

Minimum spanning trees

Another approach to classification produces a minimum spanning tree in which objects are linked by a series of line segments so that the sum of segment lengths is a minimum, there are no closed loops, and every object is connected to at least one segment. A segment's length is the dissimilarity between the objects at its ends (Chatfield and Collins, 1980, 223). Fig. 27 gives the minimum spanning tree for the sampled witnesses. Segment lengths are not to scale and angles between segments are arbitrary. Fig. 28 lists segment lengths which are actually dissimilarities calculated from the simple matching coefficients of the respective witness pairs.

Partitions are obtained from the minimum spanning tree by progressively removing the longest links. In this tree, the first segments to be removed isolate U6, then Kilpatrick's text, then U150 from the rest. Next, the remaining witnesses split into three groups. In fact, the resultant partition is exactly equivalent to one obtained by chopping a single-link hierarchical tree at corresponding dissimilarity levels (Chatfield and Collins, 1980, 224).

Minimum spanning trees provide a useful supplement to two-dimensional classical scaling maps. They help to distinguish between real proximity and apparent proximity caused by parallax effects that would not be revealed unless higher dimensions were mapped. For two witnesses to be considered close, they should appear near each other in the appropriate classical scaling map *and* the corresponding minimum spanning tree (see Finney, 1997, 131).

Non-hierarchical clustering

Non-hierarchical clustering partitions objects into a specified number of groups. Objects are initially assigned to groups by a

predetermined method, then an iterative procedure relocates objects until a measure of group compactness is optimised (Chatfield and Collins, 1980, 225). One popular method known as *k-means clustering* minimises within group sums of squares of Euclidean distances between objects. As a result, it can only be used where Euclidean distance is meaningful (Podani, 1994, 52). Euclidean distance is meaningful for dissimilarities calculated from binary data matrices but not multistate data matrices. János Podani (1994, 58) has devised a method called *global optimisation* that allows partitions to be created using any resemblance coefficient. It optimises the ratio of average within cluster distances to average between cluster distances.

The following two partitions of the sampled witnesses were obtained using k-means clustering and global optimisation, respectively. In both cases, the specified number of groups is six and the starting configuration is based on the witnesses with the greatest distances from the others. I chose to divide the witnesses into six groups to allow comparison with the partition obtained by chopping the single-link hierarchical tree of sampled witnesses at a dissimilarity of 0.19. (Chopping the single-link tree at this level results in a partition similar to the one I used in the preceding chapter.)

K-means clustering

Group 1: U6

Group 2: Attridge Bover Merk NA25 Souter Tasker Tisch UBS4
W&H

Group 3: U25 M104 M256 M1739 M1881 M2127

Group 4: Kilp

Group 5: U18 M365 M1962 TR

Group 6: U2 U150 M81 Soden Vogels

Global optimisation

Group 1: U6 Kilp

Group 2: Attridge Bover Merk NA25 Soden Souter Tasker Tisch

Vogels

UBS4 W&H

Group 3: U2 U25 M104 M256 M2127

Group 4: U150 M81

Group 5: U18 M365 M1962 TR

Group 6: M1739 M1881

The group consisting of U18, M365, M1962, and the *Textus Receptus* recurs in the partitions derived using single-link clustering, k-means clustering, and global optimisation. Another group consisting of U25, M104, M256, M1739, M1881, and M2127 recurs in the single-link and k-means partitions, but its members split into two clusters in the global optimisation partition. The modern editions also tend to group together no matter which partition method is employed. Witnesses that fall into the same groups irrespective of the partition method might be described as invariant. Groups that are comprised of invariant witnesses have a claim to authenticity. Witnesses that are classified differently depending on the partition method (e.g., U2, U150, and M81) may be termed unclassifiable while those that tend to be isolated (e.g., U6 and Kilpatrick's text) can be described as solitary.

Seriation

John G. Griffith introduced seriation methods to New Testament textual research through an article published in 1969. In essence, the sequence of witnesses in a dissimilarity matrix is rearranged to optimise the diagonal structure of the matrix (Podani, 1994, 173). This procedure tends to reveal underlying gradients. For example, seriation methods are used in archaeology to place artifacts into a time sequence. The sequence obtained for New Testament manuscripts places like witnesses in adjacent positions but is not necessarily indicative of textual age or freedom from corruption. As Griffith (1969, 405) wrote,

it cannot be too strongly emphasized that this is *not* an attempt to rank manuscripts in an order of merit. To seek to do so would be tantamount to resuscitating the long-discredited concept of a 'best

manuscript'. The sole operative criterion in the taxonomic method is the unambiguous one of likeness and difference, which have nothing to do with the goodness or badness of the readings under consideration.

Fig. 29 gives the result of a rearrangement of the sampled witness dissimilarity matrix derived by one of the *SYN-TAX* computer programs. Ranges of dissimilarities are represented by numerals ('1': 0.00 - 0.17; '2': 0.17 - 0.32; '3': 0.32 - 0.46; '4': 0.46 - 0.61). Abrupt changes between adjacent witnesses in the rearranged matrix correspond to natural group boundaries. The difference between U6 and M365 is obvious. The same goes for the difference between Westcott and Hort's text and Kilpatrick's text at the other end of the spectrum. A rough method of finding boundaries consists of counting the number of times adjacent witnesses agree in having dissimilarities within the same range for corresponding entries. This approach gives rise to the following partition, where I have chosen 14/24 agreements as the critical value for determining boundaries:

Group 1: U6

Group 2: U18 M365 M1881 M1962 TR

Group 3: U25 M104 M256 M1739 M2127

Group 4: U2

Group 5: U150

Group 6: M81

Group 7: Soden Vogels

Group 8: Attridge Bover Merk NA25 Souter Tasker Tisch UBS4 W&H

Group 9: Kilp

Some of the groups identified in this way resemble ones already isolated using other partition methods.

Principal component analysis

An article by John G. Griffith which was published in 1979 introduced principal component analysis to New Testament

textual research. According to Chatfield and Collins (1980, 55),

Principal component analysis consists of finding an orthogonal transformation of the original variables to a new set of uncorrelated variables, called principal components, which are derived in decreasing order of importance.

This is perhaps the best known form of multivariate analysis. As mentioned before, J. C. Gower showed that its results are equivalent to those of classical scaling if binary data matrices and the simple matching coefficient are employed. Fig. 30 plots the first two principal components of the sampled witnesses. Apart from a rotation and reflection, the witnesses do indeed have the same configuration as in the corresponding classical scaling map of fig. 2, although this is difficult to see because the witnesses are compressed into a small area.

For the technically minded, analysis of the sampled witness data matrix found 44 positive eigenvalues. This represents the number of principal components in the data, which is based on 71 binary units. (One of the units had to be discarded to avoid a singularity problem, so the analysis was actually based on 70 units.) These 71 units arose from 43 of the multistate variation units found in the UBS4 apparatus. The fact that the number of principal components is nearly equal to the number of variation units implies that the UBS4 variation units are independent of each other, as was assumed in section 8.2.1.

The relationship between each original variable (i.e., unit) and each principal component can be calculated during the analysis. As a result, units as well as witnesses can be plotted against the principal components. Fig. 30 is a 'biplot' that includes units in this manner. Units that are highly correlated with the plotted principal components have large displacements from the origin. As an example, unit '25' has reasonably strong correlation with both of the first two principal components. (A unit's number is given by its position in the data matrix, so unit '25' is the 25th unit.) Units are linked to the origin by line segments to

distinguish them from witnesses. Units that are strongly correlated with the principal components are suitable candidates for use in witness classification schemes (Kvalheim *et al.*, 1988, 139). This is because principal component analysis identifies readings that are the most efficient indicators of variation among witnesses. These readings are at least as efficient as ones identified for the purpose using *ad hoc* methods.

Returning to fig. 30, units '41' to '53' have the strongest positive correlation with the first principal component. These units, which are superimposed because they are not independent, appear to the right of unit '4'. Units '16' to '19' have the strongest positive correlation with the second principal component and are also superimposed. They are located just above unit '61'. Unit '13' has the strongest negative correlation with the first principal component, while unit '37' has the strongest negative correlation with the second principal component.

Just as witnesses can be grouped by inspection of a classical scaling map, units can be grouped by inspection of a principal component analysis biplot. Readings that represent a group of readings can be identified in order to reduce the number needed for a classification scheme. In the present case, units '41' to '53' could be represented by just one of this group because they coincide. In the same way, units '16' to '19' could be represented by, say, unit '16'. A reasonably adequate scheme for sorting witnesses according to the first two principal components could then be constructed by considering only units '41', '16', '13', and '37'.

Correspondence analysis

The aim of correspondence analysis is to find an arrangement of objects and variables that best reveals their mutual correspondence. Thus, the positions of variables should reflect the positions of objects and vice versa (Podani, 1994, 122). Fig. 31 is the result of correspondence analysis upon the sampled witness data. Whereas the displacement of a unit relative to the origin is important in a principal component analysis biplot, the

significant factor in a correspondence analysis biplot is the proximity between units and witnesses. Those that are close together, such as U6 and unit '4', tend to be associated with each other. This method is useful for finding readings that distinguish one group of witnesses from another, and for grouping readings that correlate with one another. As far as witnesses are concerned, correspondence analysis of the sampled witness data produces essentially the same configuration as obtained with classical scaling and principal components analysis.

If maps have not already been obtained, this mode of analysis represents a good choice because it produces maps of both witness and unit configurations simultaneously. One drawback of correspondence analysis is its susceptibility to the same singularity problems as principal component analysis. If a singularity is encountered, it is necessary to remove the offending variable or variables from the data matrix. This highlights what seems to be an advantage of classical scaling. I have not encountered singularity problems in producing any of the classical scaling maps of this thesis.

Canonical variates analysis

A number of multivariate techniques set out to reduce the effective dimensionality of a data set by finding independent axes that point along directions of maximum variation. Axes found by principal component analysis coincide with directions of maximum dispersion among objects. As classical scaling finds the same axes for dissimilarity matrices generated from binary data matrices using the simple matching coefficient, its axes also point along directions of maximum object dispersion. For this reason, its maps present optimum views of object variation.

Rather than finding directions that maximise object dispersion, canonical variates analysis finds axes that maximise the separation between predetermined groups of objects. It does this by a procedure that maximises dispersion among groups relative to dispersion within groups. For a given partition, canonical variates analysis reveals differences between the resultant groups

as effectively as possible (see Chatfield and Collins, 1980, 153-159; Podani, 1994, 143-153).

Figs. 32 to 34 present the canonical variates analysis results for part of the sampled witness data. The predetermined groups are taken from the single-link clustering tree shown in fig. 26. Six groups emerge if this tree is chopped at a dissimilarity level of 0.19. Three are comprised of solitary witnesses (i.e., U6, U150, and Kilpatrick's text) and the other three contain more than one witness each. The analysis is based on a data matrix that omits the solitary witnesses and a partition that divides the other witnesses into the remaining three groups:

Group 1: U18 TR M1962 M365

Group 2: M81 U2 Bover Merk Tisch Souter Attridge NA25 Tasker
UBS4
Vogels W&H Soden

Group 3: U25 M104 M256 M2127 M1739 M1881

Group numbering is normally arbitrary, but in this case it has been chosen to coincide with the numbering used in my tentative classification scheme. Certain units that cause singularities in the form of 'divide by zero' errors have been discarded from the data matrix. These include units that display no variation (i.e., are all 'ones' or all 'zeros') and those that display no variation within any of the three groups (e.g., one group has all 'zeros' and the other two have all 'ones'). In addition, units that are exactly the same as the preceding one (e.g., units '17' to '19') have been discarded to prevent superimposed unit numbers in the diagrams. Altogether, the number of units is reduced from 71 to 45. These 45 have been divided among three data matrices of 15 units each because the *SYN-TAX 5* analysis will not run if there are more variables (i.e., units) than objects (i.e., witnesses).

The diagrams are biplots that include witnesses and units. Group identification numbers are printed at the centres of the respective groups. Plotted around each group is a confidence region that is expected to contain 95% of the respective group members. The radius of each confidence region is 2.45 canonical axis scale

units (Podani, 1994, 148). Group members are plotted as light grey points without sigla. (This constraint is imposed on the biplots by SYN-TAX 5.) Unit numbers are plotted along with line segments joining them to the origin, which is also the group centroid (i.e., the 'centre of gravity' of all the witnesses). Only two canonical axes exist here because the maximum number of canonical variates is one less than the number of predetermined groups.

If the 95% confidence regions of two groups overlap, as occurs for groups 1 and 3 of the first part (fig. 32), then the given partition is not terribly good at discriminating between the groups. Groups become better defined as the variation among groups, which is indicated by separation along the canonical axes, becomes relatively great with respect to the variation within groups, which is indicated by the radius of the confidence regions. Comparison of figs. 32, 33, and 34 shows that group definition tends to improve in successive parts of Hebrews. Improved group definition implies less complicated relationships among witnesses. Given that independent scribal activity results in more complicated relationships than those which follow from accurate (i.e., uncritical) copying alone, this trend could be graphic evidence of the scribal tendency to concentrate corrective efforts at the beginning of a book.

The position of each variable is determined by its correlation with the respective canonical axes. Variables with the largest components along the canonical axes have the greatest ability to discriminate between groups. In fig. 32, units '16' and '20' are strongly correlated with the first canonical axis. They can be expected to discriminate between witnesses of groups 1 and 3 on the one hand, and group 2 on the other. Units '5' and '11' have reasonably large components along the second canonical axis. They can be expected to discriminate between group 1 witnesses and group 3 witnesses. The relatively small components of units '8', '9', '10', and '15' imply that they have little discriminatory power with respect to these groups.

Canonical variates analysis can be used to assign an unclassified witness according to the predetermined groups. The canonical variates corresponding to a particular object (i.e., witness) are linear combinations of the object's unit values:

$$C_i = a_{i1}U_1 + a_{i2}U_2 + \dots + a_{iP}U_P$$

where i is the number of the canonical variate (one for first, two for second, etc.), a_{in} is the coefficient for canonical variate i and unit n of the witness in question, U_n is the value of unit n , and P is the number of units. It is necessary to perform canonical variates analysis on a set of reference witnesses using a predetermined partition before other witnesses can be classified. Once this has been done, an unclassified witness can be assigned to one of the given groups by calculating its canonical variates and comparing them with the coordinates of group centres in the existing canonical variates analysis diagram. The witness is then assigned to the group whose centre is least distant. (As an alternative, a data matrix that includes the reference witnesses and the witness to be classified can be subjected to the full canonical variates analysis, starting with a fresh partition obtained via the corresponding dissimilarity matrix.)

Canonical variates analysis makes certain assumptions concerning the set of data upon which it operates. The data are assumed to be composed of systematic and residual components. The systematic component corresponds to an object's group mean while the residual component corresponds to the object's displacement from the group mean caused by what might variously be described as random fluctuation, stochastic noise, or, in the scribal context, independent creative events. The model also assumes that object values represent random samples from normally distributed populations that all possess the same standard deviation. If these conditions are seriously violated then results of the analysis may not be reliable.

Although I do not intend to test whether the conditions are satisfied in the present case, there is some justification for

believing that they are. According to Moore and McCabe (1993, 399),

the central limit theorem says that the distribution of a sum or average of many small random quantities is close to normal. This is true even if the quantities are not independent (as long as they are not too strongly associated) and even if they have different distributions (as long as no one random quantity is so large that it dominates the others). The central limit theorem suggests why the normal distributions are common models for observed data. Any variable that is a sum of many small influences will have approximately a normal distribution.

Each row vector in a binary data matrix can be regarded as having a systematic component due to its heredity, and a residual component due to variations caused by scribal creativity. The residual component accumulates over many copying events. Mixture aside, numbers of variations from the common group ancestor for a set of witnesses should therefore conform to the normal distribution. Whether the standard deviations within each group are the same is another question. A difference in the dispersion of groups was noticed in the last chapter, particularly in the spelling maps. Fortunately, the procedure should remain valid under these circumstances, given that the analogous one-dimensional procedure is robust against violations of the requirement for equal standard deviations (see Moore and McCabe, 1993, 722-3).

The one-dimensional procedure just referred to is called analysis of variance or ANOVA. It is a formal test of group separation for one dimensional data that conforms to the model outlined before. It works by comparing the ratio of among-group dispersion to within-group dispersion with the F statistic, named in honour of Sir Ronald A. Fisher. The multivariate generalisation of this test is called multivariate analysis of variance or MANOVA. The 95% confidence regions of the canonical variates biplots provide an indication of whether apparent groups can be regarded as truly separate. The MANOVA test procedure is available should it be

desired to conduct a formal test of significance for group separation (see Chatfield and Collins, 1980, 140-153).

Existing classification methods

Bart D. Ehrman produced a useful survey of existing classification schemes for New Testament documentary evidence (1987, 22-45). He identified three approaches: collation against the *Textus Receptus*; quantitative analysis; and the construction of group profiles. The strengths and weaknesses of these techniques can be understood by reference to multivariate analysis concepts. In fact, all three existing techniques have multivariate analysis counterparts that are superior because they represent optimal solutions.

The first classification method characterises manuscripts according to their agreement in variation from the *Textus Receptus*. It was popular until Bruce M. Metzger pointed out certain shortcomings of the method. Firstly, it is incapable of isolating readings characteristic of a particular group of witnesses if those readings recur in the *Textus Receptus*. Also, the level of agreement in variation from the *Textus Receptus* is not a reliable indicator of textual affiliation because two manuscripts with some number of mutual variations from the *Textus Receptus* might vary from each other much more frequently over the same span of text (Ehrman, 1987, 34-35).

These problems are apparent from the perspective afforded by multivariate analysis. Measuring agreement in deviation from the *Textus Receptus* is a one-dimensional comparison procedure. It considers only one row (or column) of the dissimilarity matrix for a set of witnesses, with a corresponding loss of relational information. Using a geographical analogy, this is like trying to construct a map of point locations by measuring distances from a single point. Such a procedure is incapable of giving an adequate representation if the configuration of points is multi-dimensional. The same weakness is common to any classification that arranges witnesses according to a single underlying parameter, including my scheme and other schemes such as seriation.

Nevertheless, agreement in variation from the *Textus Receptus* is a reasonably effective first step in classification. The *Textus Receptus* happens to lie towards one extreme of the most important underlying axis discovered through classical scaling. As a result, comparison against the *Textus Receptus* approaches the efficiency of multivariate techniques in separating witnesses along their most important direction of variation. To become capable of considering other important directions of variation, the method would have to be supplemented with measurements of proportional variation from other judiciously chosen witnesses.

Quantitative analysis, developed by Ernest C. Colwell in collaboration with Ernest W. Tune, does precisely this. It requires large sections of the texts that are being classified to be collated against a number of reference manuscripts that have been selected to represent the full range of variation found among New Testament witnesses (Ehrman, 1987, 37). Whereas Colwell and Tune's reference manuscripts have been chosen empirically, multivariate analysis provides the basis for an optimum selection method.

There is not much point in using multivariate techniques to choose these reference manuscripts because the representation of data produced by the requisite multivariate analysis is at least as good as one produced by quantitative analysis. Nevertheless, I will continue on this course because it offers some insight into the fundamental nature of quantitative analysis, which has been a popular technique.

The best reference witnesses are those that offer the greatest potential for discrimination among witnesses along the classical scaling axes. Witnesses found at the extremities of each classical scaling axis are a logical choice. Fig. 2 shows that for the sampled witnesses, M365 and Nestle's 25th edition have the most extreme positions along the first axis, while U6 and M81 stand at the extremities of the second axis. It is only necessary to specify

one extreme witness for each axis, perhaps the one that stands closest to the notional original text, if the text's approximate position is known. According to this approach, Nestle's 25th edition and M81 would provide suitable reference witnesses corresponding to the first two classical scaling axes of the sampled witness maps.

Classification then consists of collation against the reference witnesses and calculating proportional agreements with them. This results in coordinates relative to the reference witnesses that roughly correspond to genuine classical scaling axis coordinates. A reference witness can be obtained for a higher dimension by plotting the classical scaling map for that dimension and, say, the first dimension. Once a full array of reference witnesses has been identified in this manner, a witness can be classified according to its proportional agreements with reference witnesses in as many dimensions as deemed necessary for an adequate classification.

An indication of the resultant classification's efficiency is provided by the percentages of total variation explained by respective classical scaling axes. The first two classical scaling axes of the sampled witnesses account for a total of 44% (i.e., 29% + 15%) of the variation inherent in their dissimilarity matrix. Given that extreme witnesses do not discriminate as well as classical scaling axes, these percentages represent a theoretical limit to the resultant classification's efficiency. A classification based on agreements with an extreme witness in the first dimension can be 29% efficient at best. One based on the *Textus Receptus* will be less efficient, even more so because this text is not an extreme witness in the first dimension. The following table gives the number of dimensions (i.e., axes) required to achieve various percentages of explained variation for the sampled witnesses:

<i>Number of dimensions</i>	1	2	3	4	5	6	7
8							
<i>Cumulative percentage</i>	29	44	53	60	66	71	76
80							

Numerous dimensions are required to explain substantial proportions of the total variation. It is difficult to visualise more than three dimensions without resorting to rather esoteric methods. The unfortunate implication is that comprehensive classification schemes are difficult to comprehend.

Colwell and Tune's method defines group membership according to an empirical rule that manuscripts of the same group agree in at least 70% of 'genetically significant' variations and are separated from manuscripts of other groups by a margin of at least 10%. A study by W. L. Richards showed that the among group and within group levels of agreement should be set on a case by case basis (Ehrman, 1987, 37-38, 40). From a statistical point of view, it is better to first establish group boundaries using some partition technique, then to test the validity of the partition using canonical variates analysis or MANOVA. The important factor is not an absolute level such as 70% agreement or 10% separation, but a ratio of among group dispersion (i.e., the 'distance' between group centres) to within group dispersion (i.e., the 'width' of groups).

Only 'genetically significant' variations are counted in Colwell and Tune's method. This is done to eliminate the possibility of counting coincidental agreements between witnesses. That is, readings that are likely to be the result of independent scribal alterations as opposed to accurate copying are excluded from consideration. Metzger suggested that such alterations might include changes of word order, substitution of synonyms, deletion or insertion of articles, and changes between certain tenses. Not everyone who uses the method excludes readings of this kind. For instance, Gordon D. Fee includes all variation units in his analysis of the text of Codex Sinaiticus in the Gospel of John (Ehrman, 1987, 35, 37).

Whereas it is commendable to restrict the analysis in this way, the potential exists for variation units that convey useful genetic information to be ignored because they fall into one of the

categories of independent scribal alterations. It is exceedingly difficult to discern the motives of an ancient scribe from our vantage point. It is therefore hazardous to deem any reading as insignificant. It would be reasonable to exclude certain classes of variation if it could be demonstrated that they were very likely to be independent creations. Such classes could be identified by a comprehensive study of scribal habits of the kind carried out by James R. Royse (1981).

An alternative procedure considers all variations on an equal basis but uses a model that allows for the possibility of coincidental agreement between witnesses. Geoffrey P. Farthing (1994) takes this approach when considering the implications of the premise that a certain proportion of readings are independent scribal creations. A similar data model that assumes witnesses to be comprised of systematic and random residual components stands behind the confidence intervals, probability ellipses, and canonical variates analysis discussed earlier.

Models of this kind allow all variation units to be counted in the knowledge that some of the evidence will be randomly directed. Subsequent decisions take account of this potentially misleading evidence by means of confidence intervals. The exclusion of such spurious evidence might be considered should it be desired to improve the confidence level. Multivariate analysis can identify units that contribute little to discrimination. Their elimination allows 'noise' to be reduced while retaining useful information.

Group profile methods offer another solution to the problem of coincidental agreement. They rely on the identification of readings that are characteristic of groups of witnesses. This approach was pioneered by Edward A. Hutton who proposed a method based on 'triple readings', which are variation units where Alexandrian, Western, and Byzantine manuscripts have distinct readings. Ernest C. Colwell took up the method, introducing 'multiple' variation units that have at least three distinct forms, each of which is supported by major witnesses or groups of

witnesses. Other variations include the Claremont Profile Method of Frederik Wisse and Paul McReynolds, and the Comprehensive Profile Method developed by Bart D. Ehrman (Ehrman, 1987, 31, 36, 43-45). The Institute for New Testament Textual Research also uses a set of test readings to evaluate witnesses in its *Text und Textwert* series.

All group profile methods are based on a preliminary collation that identifies readings suitable for constructing a profile. Previously unclassified witnesses are assigned to groups identified in the collation according to their patterns of agreement in the profile readings. The more comprehensive the preliminary collation, the better a derivative group profile will be able to characterise an unknown witness.

Principal component, correspondence, and canonical variates analysis biplots are useful for identifying profile readings. Principal component analysis shows which readings are the best discriminators with respect to witness dispersion. Correspondence analysis shows which readings are associated with particular witnesses or groups of witnesses. Canonical variates analysis identifies readings that are most efficient for discriminating between predetermined groups. The profile methods are usually concerned with separating witnesses into groups identified in the preliminary collation, a task for which canonical variates analysis produces optimal results. In other words, group profile methods can do no better than canonical variates analysis when it comes to assigning witnesses to predetermined groups.

It has often been said that complete collation of all extant manuscripts is beyond the realms of practicality. I do not agree with this view. In these days of electronic communication there is no reason why a coordinated effort could not be made to complete the task, starting with the most important manuscripts first. There are about 5000 Greek manuscripts. Surely there are 5000 people in the world (i.e., one in a million) who are interested enough to adopt a manuscript, learn the rudiments of

transcription, and go to work. It would be up to the coordinators to apply quality control measures to ensure the integrity of the end results.

As long as this important undertaking is neglected, profile methods will remain the only viable means of obtaining an overall estimate of group structure among New Testament manuscripts. If the requisite preliminary collation were based on the papyrus and uncial manuscripts alone, most of the variation that is important for establishing the ancient text would be captured. After this, one of the clustering methods described before could be applied to find a partition. Next, canonical variates analysis could be applied to determine the best possible test readings and the most efficient possible classification system for the given partition. As demonstrated in this thesis, a number of aspects of the classification process just outlined can be automated by use of computers.

Perhaps the most popular existing classification scheme for New Testament manuscripts is the division into text-types that are usually labelled Byzantine, Alexandrian, Caesarean, and Western. Some of the text-types have alternative labels, the reality of the Caesarean category is subject to some doubt, and the Western label is usually placed within inverted commas to show that it does not necessarily hail from the West. A recent rendition of this scheme by Eldon Jay Epp (1993b, 283-295) replaces the usual categories with ones labelled 'A', 'B', 'C', and 'D'. These categories are intended to correspond to groups found among the earliest manuscripts:

Group A (cf. Alexandrinus): Koine or Byzantine

Group B (cf. Codex B): P75, U3 (i.e., B), P66, U1, M33

Group C (cf. Caesarean): P45, U32 (i.e., W; only in Mark), family 13

Group D (cf. Codex D): P29, P48, P38, U171, U5 (i.e., D)

These roughly correspond to the conventional text-types, but do not suffer from the logical weakness of classifying earlier

witnesses according to their affinities with later ones. The mnemonics following each group title are those suggested by Epp to help associate the new categories with the conventional ones. They are meant as guides and are certainly not to be taken as rigid rules, especially in the case of group C and the so-called Caesarean text-type (Epp, 1993b, 289-294).

My preliminary results confirm the existence of two groups in Hebrews that correspond well with two of the groups presented here: Epp's group A corresponds to my group 1, and his group B corresponds to my group 2. The third group identified in my analysis may well correspond to Epp's group C. (The matching sequence is not coincidental. I named my groups 1, 2, and 3, so as to correspond with Epp's groups A, B, and C.) A fourth group that includes U6 (which is frequently described as belonging to the Western text-type) may exist. If so, then it would correspond to Epp's group D, and the correspondence between my scheme and Epp's would be complete.

Epp's scheme assumes that there is a natural division of early New Testament witnesses into four groups. At the moment, there is insufficient evidence to suggest that a four-way division is optimal. In order to establish the basic scheme's validity, it is necessary to subject the earliest New Testament manuscripts to cluster analysis, followed by canonical variates analysis or MANOVA to confirm group separation. A major obstacle to the requisite cluster analysis is the lack of multiple coverage of the same parts of the New Testament by early manuscripts. Fortunately, books such as Luke and John are well represented. Portions of these books for which relatively large numbers of early (say, pre-fourth century) witnesses exist would constitute a suitable starting place for an investigation into the group structure of early New Testament witnesses.

In the course of his discussion, Epp (1993b, 291) writes,

A text-type is not a closely concentrated entity with rigid boundaries, but is more like a galaxy — with a compact nucleus

and additional but less closely related members which range out from the nucleus toward the perimeter. An obvious problem is how to determine when the outer limits of those more remote, accompanying members have been reached for one text-type and where the next begins.

This analogy of galaxies is appropriate for New Testament witnesses, as demonstrated by the maps of group affiliation found in figures 32 to 34. The nucleus is not necessarily compact, but separation between 'galaxies' can nevertheless be clear. Canonical variates analysis provides the optimum means of defining group boundaries and identifying witnesses that do not fit within them.

Stemmatic classification methods

So far, stemmatic classification techniques have not been mentioned. These take account of the fact that manuscript transmission is essentially a genetic process, with each manuscript being a more or less exact reproduction of its parent manuscript (or manuscripts if more than one exemplar is involved). Westcott and Hort used stemmatic methods to eliminate the Byzantine text from consideration in establishing the original text. Other efforts in this area include the research of B. H. Streeter, Dom Henri Quentin, Sir Walter W. Greg, Archibald A. Hill, and Vinton A. Dearing (see Metzger, 1992, 163-173). More recently, studies by James D. Price (1987), Gerd Mink (1993), and Geoffrey P. Farthing (1994) have taken varying approaches to New Testament genealogy. In another important development, Barbrook, Howe, Blake, and Robinson (1998) have applied techniques developed in evolutionary biology to discover probable stemmata for the complicated textual tradition of Chaucer's *Canterbury Tales*.

With the exception of the work just noted, efforts to discover group structure among New Testament witnesses by stemmatic methods have been neglected in recent times. This is probably because of a perception that complicating factors such as mixture make the problem too complex to be solved. The progress

reported by Barbrook *et al.* in analysing another complex tradition (which also has manuscripts that exhibit mixture) calls for the same techniques to be applied in the New Testament context. The underlying mathematical models of stemmatic procedures are quite distinct from those of clustering procedures. As a consequence, the results of stemmatic approaches would provide an independent picture of group structure among New Testament witnesses. If these results were to compare well with the results of the non-stemmatic approaches of multivariate analysis, we could be confident of their veracity.

Proceeding along these lines, the textual data collected for this thesis could be analysed using the techniques of evolutionary biology. Another suitable body of data is found in the *Text und Textwert der griechischen Handschriften des Neuen Testaments* series (see Benduhn-Mertz, Mink, and Bachmann, 1991). The data contained in these volumes has the advantage of extending over more of the New Testament than my data. It would be a most useful exercise to analyse the data contained in these volumes using both stemmatic and multivariate techniques, then to compare the results.

Validity of my classification scheme

My tentative classification can now be evaluated in the light of the preceding discussion. Its groups compare quite well with those found using both hierarchical and non-hierarchical clustering. Being a one-dimensional approach (considering position relative to the first classical scaling axis alone) it leaves much to be desired. Certain group members are peripheral or misplaced altogether. Of particular concern is U150, which has a strong tendency to switch between groups depending on the chosen mode of analysis. Nevertheless, my scheme is superior to one that is based on proportional agreement with the *Textus Receptus*.

This positive assessment means that the results of the last chapter which depend on my classification scheme remain valid. The potential for incorrect classification (and consequent spurious

results) is reduced by allowing borderline witnesses to have joint membership in adjacent groups. While being trustworthy, results that depend on my classification scheme should be regarded as only a first approximation to the actual situation. My scheme could be improved by taking account of the second and third classical scaling axes as well.

Canonical variates analysis on the basis of a partition discovered through single-link clustering performs well and is optimal with respect to group separation. Regardless of the chosen classification technique, there is a general need for more data. Completely transcribed witnesses produce comprehensive collations. This minimises sampling errors of the kind that give rise to uncertain witness positions in classical scaling maps. Including more witnesses provides more data from which to discern group structure. Block mixture can be detected by dividing the analysis according to textual sections. Witnesses that are found to be free from block mixture can be analysed over larger sections of text with a corresponding decrease in uncertainties. There is great potential for clarifying the textual history of the New Testament through applying computer-assisted analysis to large bodies of textual data.

Collation revisited

At this point, collation can be revisited with a view to suggesting improvements that will enhance its utility as a preliminary step in analysis. Reduction in systematic errors, minimisation of sampling errors, and maximisation of relational information can be sought for a given set of data. There is also potential for adapting existing collation results for the purpose of useful analysis.

Binary data

The main advantage of a binary representation is that a wider range of analytical techniques are available for binary data than for multistate data. Another advantage is that a number of different multivariate techniques produce similar or equivalent

results when applied to binary data.

The worst systematic error encountered in my binary collation scheme relates to the spelling perspective. As will be recalled, my scheme collates entire verses that contain alterations. As a consequence, the existing spelling in a verse tends to reduce a corrector's displacement from the preceding scribe's spelling position. The solution to this problem is simple: only those words that have been altered should appear in the final data matrix.

Another area where my collation method can be improved concerns maximisation of relational data. At present, data matrices only incorporate those witnesses that are extant for all of the verses in which the principal witness exists. This strategy was adopted to avoid the possibility of 'divide by zero' errors that arise when an attempt is made to calculate the dissimilarity between two witnesses that do not exist for any of the same text segments. Consequently, any witness that is missing only a few of the verses common to a particular set of witnesses will be excluded from the resultant data matrix and subsequent analysis.

It is useful to include as many witnesses as possible if overall group structure is being examined. Also, it is sometimes desirable to make a direct comparison of witnesses in order to investigate relationships that are implied by indirect comparisons (cf. the texts of Cyril of Jerusalem and Gregory of Nyssa). The number of witnesses in my principal data matrices can be increased above the present number by setting a minimum number of units held in common for any pair of witnesses. This procedure maximises relational data at the cost of increased sampling error.

The minimum number of common units might be calculated on the basis of probability ellipses. If, for example, it was regarded as acceptable to have an uncertainty in dissimilarities that corresponds to a 95% probability ellipse of radius 0.1 classical scaling axis units, then the previously derived equation for the radius of probability ellipses ($\text{radius} = 0.78 / \sqrt{n}$) implies that the

number of units should be at least 61.

The refinements just outlined could be achieved in the following way:

- (1) Make a binary data matrix using the synthetic text method;
- (2) Classify each word as subject to textual variation, spelling variation, textual and spelling variation, or no variation. This step would be facilitated by the 'parallel' transcription approach described in the chapter on collation;
- (3) Produce separate textual and spelling variation data matrices by selecting textual or spelling variations alone.

This procedure would eradicate words that do not exhibit the kind of variation under investigation, whether spelling or textual. (The same applies to other kinds of variation as well.) Given that a minimum number of common units had been specified, the data matrix production step could process the initial data matrix of each principal witness as follows:

- (1) Count the number of common units for each pair of witnesses;
- (2) Eject from the data matrix one member of the witness pair that has the least number of common units, provided that number is less than the required number. (A logical choice would be to eject the witness with the lesser number of units.);
- (3) Repeat steps (1) and (2) until the number of columns in the data matrix ceases to change.

Another possible algorithm would eject members of all witness pairs that do not meet the minimum requirement at once instead of at a rate of one witness per cycle. This would be much faster, but I think that the resultant data matrix could contain less witnesses than obtained with the given algorithm. As an added refinement, parts of the data matrix that cause singularity problems for the desired subsequent analysis could be removed as well. For example, discarding rows (i.e., units) that exhibit no variation will prevent divide by zero errors in principal component and correspondence analysis.

Multistate data

Conventional collation results are typically comprised of multistate data because variation units can have more than two readings. In order to apply multivariate analysis, a mode of analysis that tolerates multistate data can be chosen, or else the multistate data can be transformed to binary data. As discussed before, the multistate approach is somewhat restrictive by comparison with the binary approach, although it is by no means impractical. For this reason, it is worthwhile to transform multistate data to a binary representation, thereby making conventional collation results accessible to the techniques already demonstrated.

Any multistate variation unit with n states can be represented with n binary units (Podani, 1994, 14). The collation software developed for this thesis carries out this kind of transformation. An existing collation can therefore be transformed into a binary data matrix by using the collation data to construct a set of quasi-transcriptions, as was done for the sampled witnesses. Alternatively, binary data can be obtained by selecting variation units that have only two possible readings. This selective approach can be applied to good effect provided that there is sufficient data to avoid unacceptably large uncertainties due to sampling errors. Approximately half of the variation units in the UBS4 apparatus for Hebrews are binary.

Summary

This evaluation has found that classical scaling maps are a valid means of representing the relationships between New Testament witnesses. They are not the only available representation, nor do they have a particular claim to being the best. Classical scaling does have the advantage of freedom from singularity problems when compared to techniques such as principal component and correspondence analysis. Also, its results are similar or equivalent to these other kinds of multivariate analysis for the binary data and simple matching coefficient employed in this thesis.

Binary and multistate data representations give broadly similar results but differ nonetheless. The disparity presents a significant challenge to the validity of either representation. Further investigation is required to establish which is the most apt.

Other aspects of the classical scaling technique can be varied with little effect on the results. This is true for resemblance measures and presence or absence of double zeros. Also, relative object (i.e., witness) positions are not generally affected by the objects that are plotted. This means that relationships found in a small sample of witnesses can be expected to recur in more comprehensive samples.

By contrast, the number of variables (i.e., units) has a significant effect on the resultant maps. Small sample sizes produce correspondingly large sampling errors. (In the present case, about eight units is the minimum number required for statistically significant conclusions.) Confidence intervals and probability ellipses can be constructed for binary and multistate data based on binomial theory. They are estimates of the range within which dissimilarities and witness positions are expected to lie. In general, the range is related to $1/\sqrt{n}$. A plotted position in a classical scaling map should not be regarded as the actual witness position. Rather, it marks the centre of a region within which the witness is expected to lie.

A number of multivariate techniques can be applied to the problem of classifying New Testament manuscripts, with each one liable to produce its own partition. All partitions should therefore be regarded as provisional. Some witnesses always group together while others group differently, depending on the partition technique. No obvious number of groups is apparent from my data for Hebrews. In other words, the present data implies that the common practice of dividing witnesses into three or four groups is arbitrary because other numbers of groups would be just as valid.

Certain multivariate techniques provide optimal solutions to classification problems. They are at least as efficient as existing classification schemes such as collation against the *Textus Receptus*, quantitative analysis, and group profile methods. Quantitative analysis and group profile methods can be improved through multivariate analysis because principal component, correspondence, and canonical variates analysis biplots identify the best manuscripts and readings to use in classification. However, it is better to use a multivariate technique from start to finish since it provides the best possible result under the given conditions. Canonical variates analysis is particularly well suited to classification according to predetermined groups. Despite their optimal nature, multivariate classification techniques are thwarted by a fundamental problem: our limited ability to perceive more than three dimensions and the high dimensionality of New Testament data make a comprehensive classification scheme difficult to comprehend.

Stemmatic classification methods hold promise as an independent means of confirming group structure discovered through multivariate techniques. There has been a recent advance in applying the techniques of evolutionary biology to a complex textual tradition. The same techniques can be expected to provide insights into the textual development of the New Testament.

This evaluation shows that my tentative classification scheme is as effective as can be expected for a one-dimensional approach, provided that its boundaries are understood to be fuzzy rather than crisp. Its groups recur in a number of the multivariate schemes. Results from the preceding chapter that rely on my classification scheme therefore remain essentially valid. Future work would benefit from adopting a multivariate classification scheme that takes into account more dimensions. Classifications and results would also benefit from more comprehensive data in terms of the number of variation units and the number of witnesses compared.

Even with existing data, my collation technique can be improved

by reducing systematic errors and making better use of relational information. This could be achieved by producing data matrices that are specific to points of variation alone. More relational information could be obtained if witnesses that are not extant for the same portions of text as the principal witness were included. Such an improvement in the number of witnesses compared is achieved at the cost of an increased potential for sampling errors.

The results of a conventional collation can be adapted for analysis by transformation to a binary representation. One approach involves constructing quasi-transcriptions based on the collation results and processing them with my software. A simpler approach is to select binary variation units (i.e., those with only two possible readings) from the collation.

Fig. 1: Test of Euclidean assumption

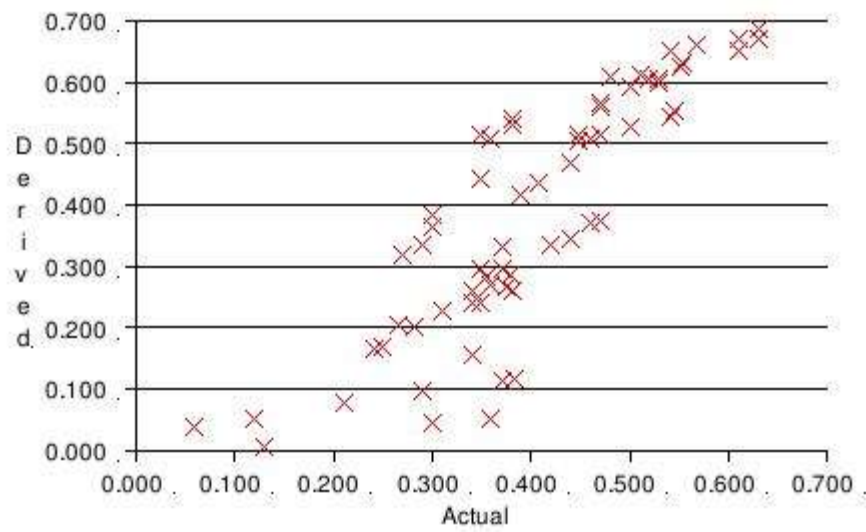
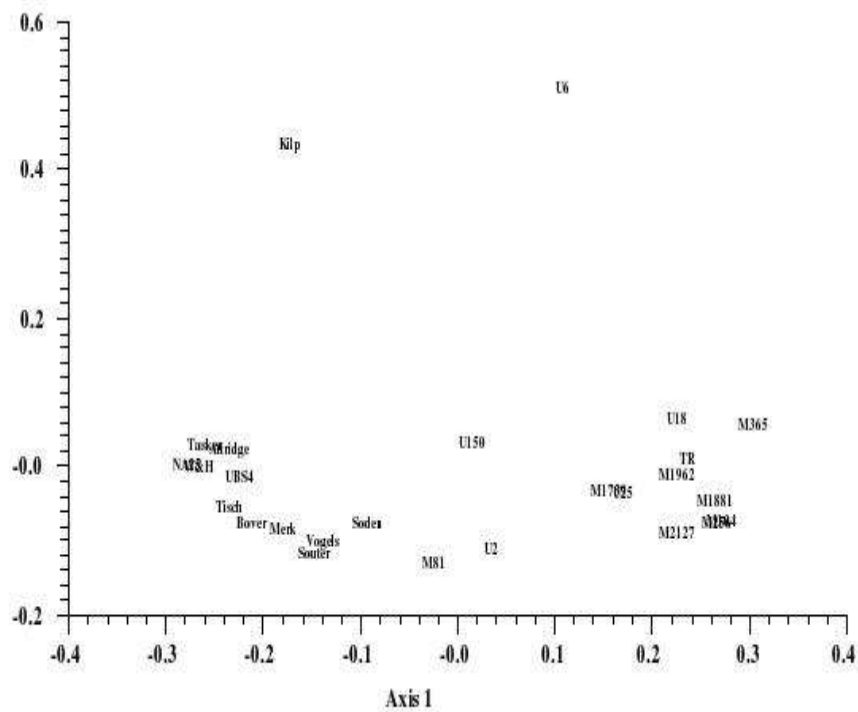
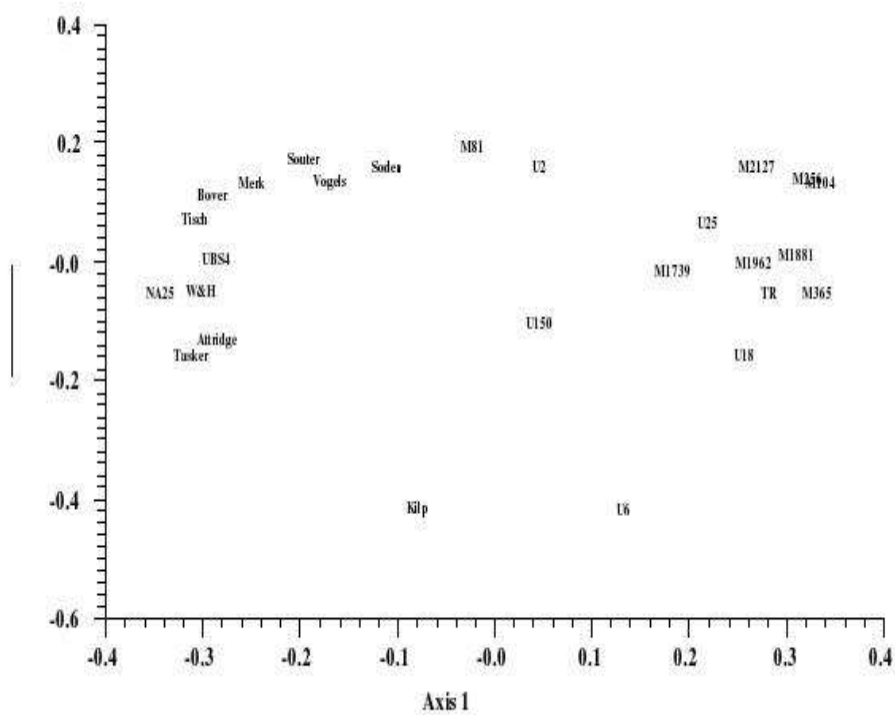


Fig. 2: Reference: Binary, simple matching



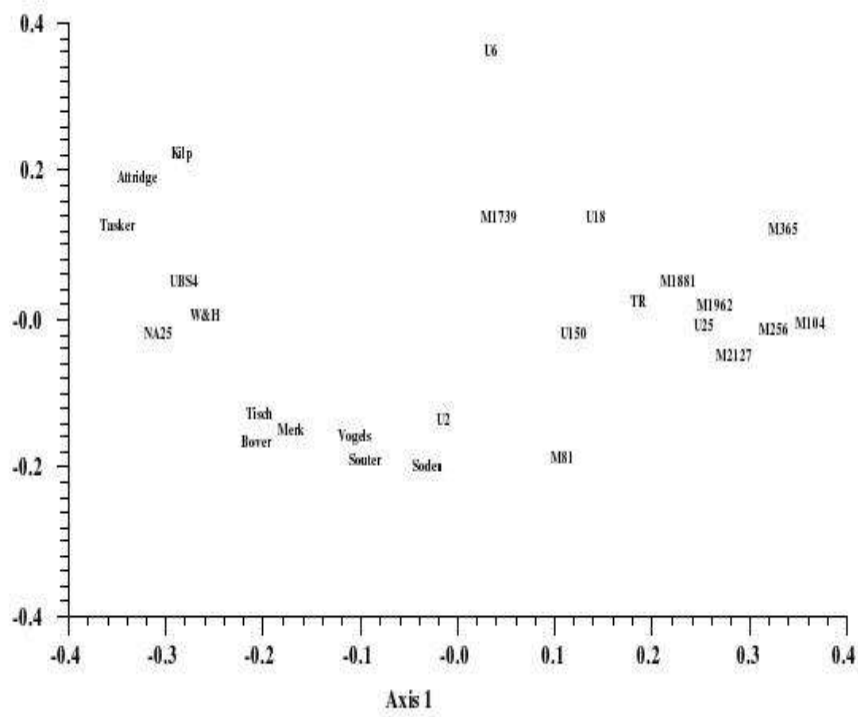
71 units; 29%, 15%

Fig. 3: Binary, Gower, double zeros excluded



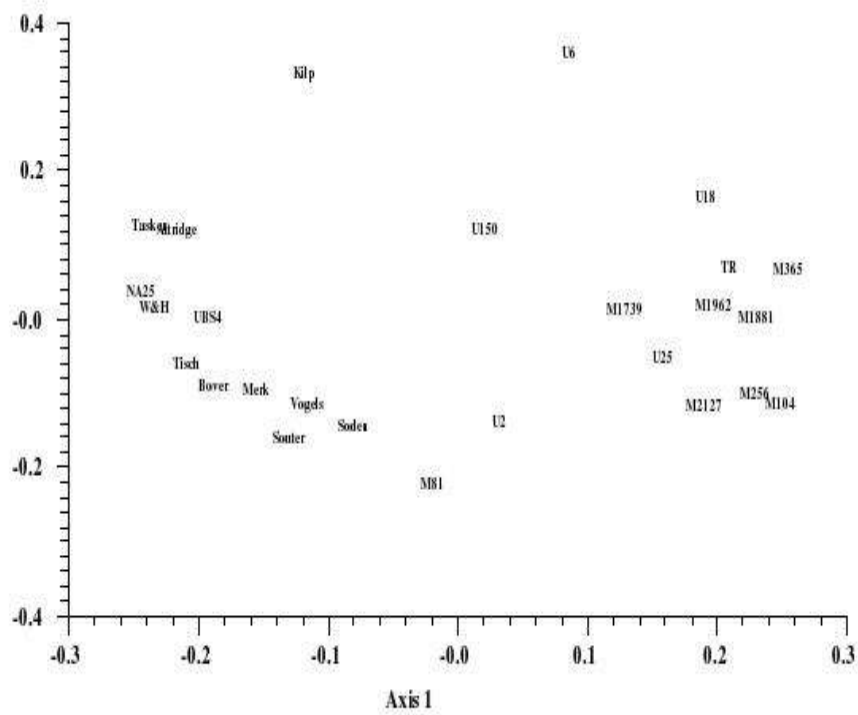
71 units; 26%, 11%

Fig. 4: Multistate, Gower, double zeros excluded



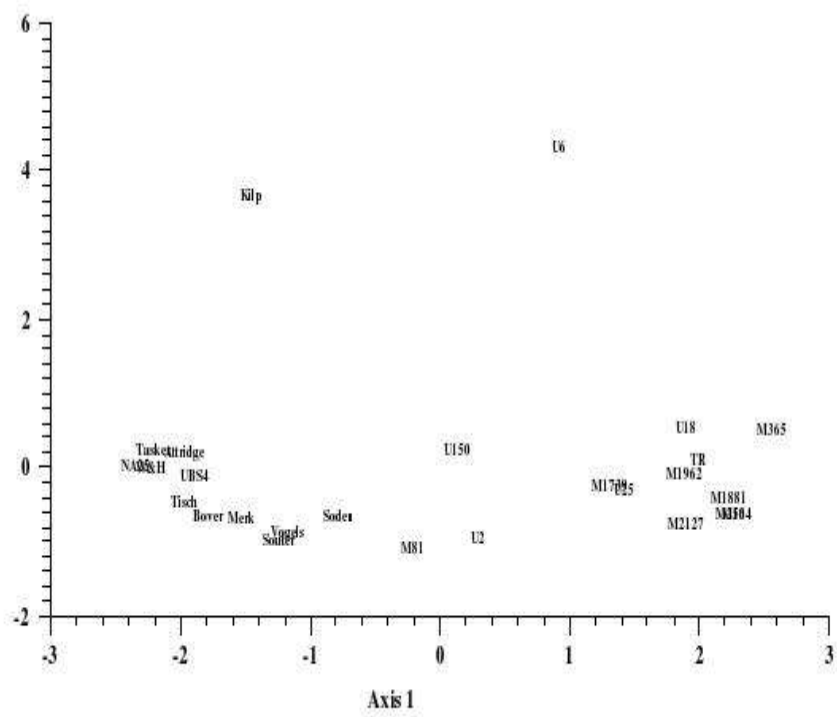
43 variation units; 29%, 11%

Fig. 5: Binary, Russell and Rao



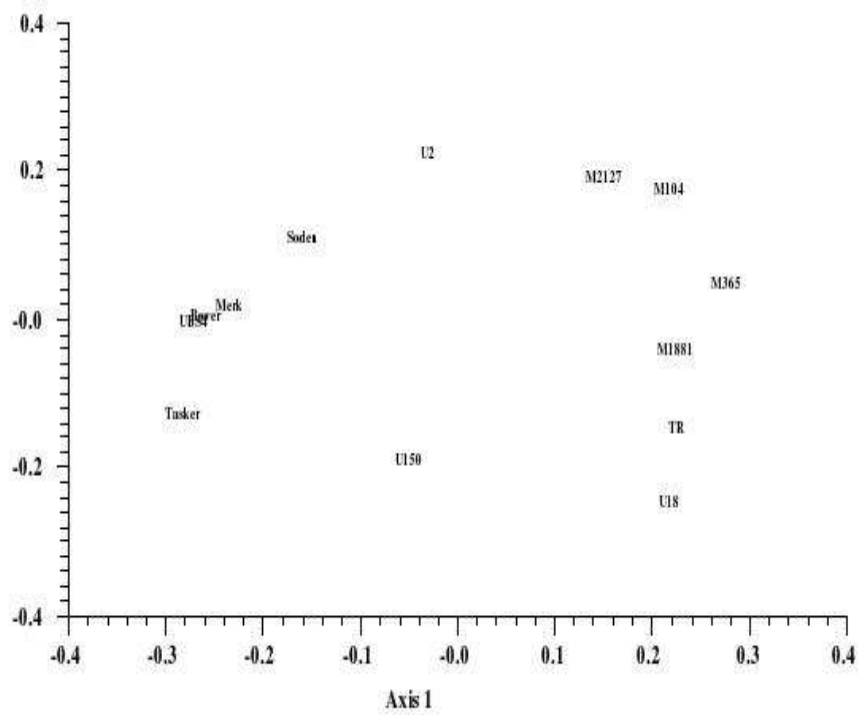
71 units; 9%, 6%

Fig. 6: Binary, Euclidean



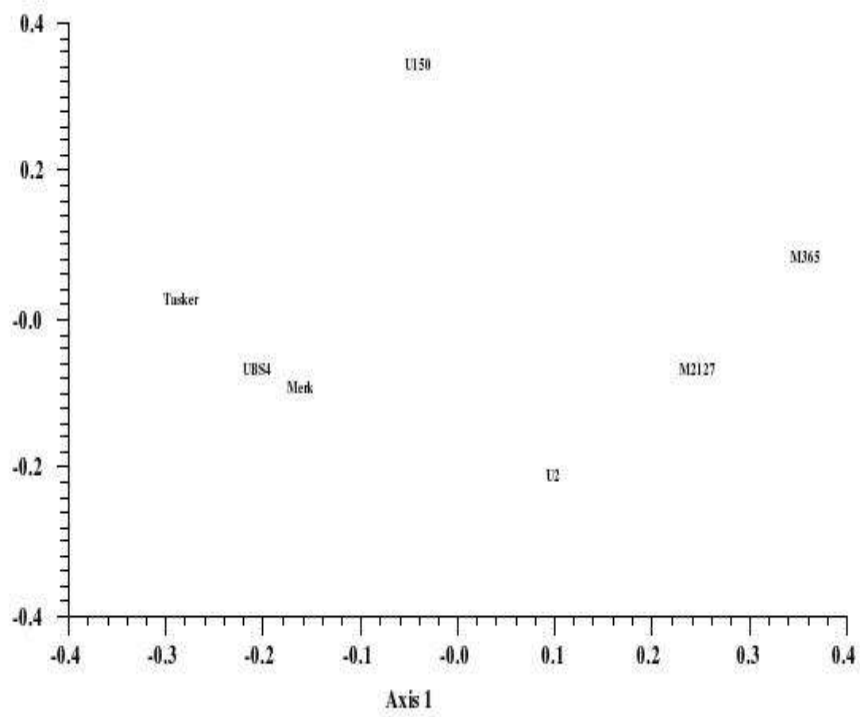
71 units; 29%, 15%

Fig. 7: Every second witness: First cycle



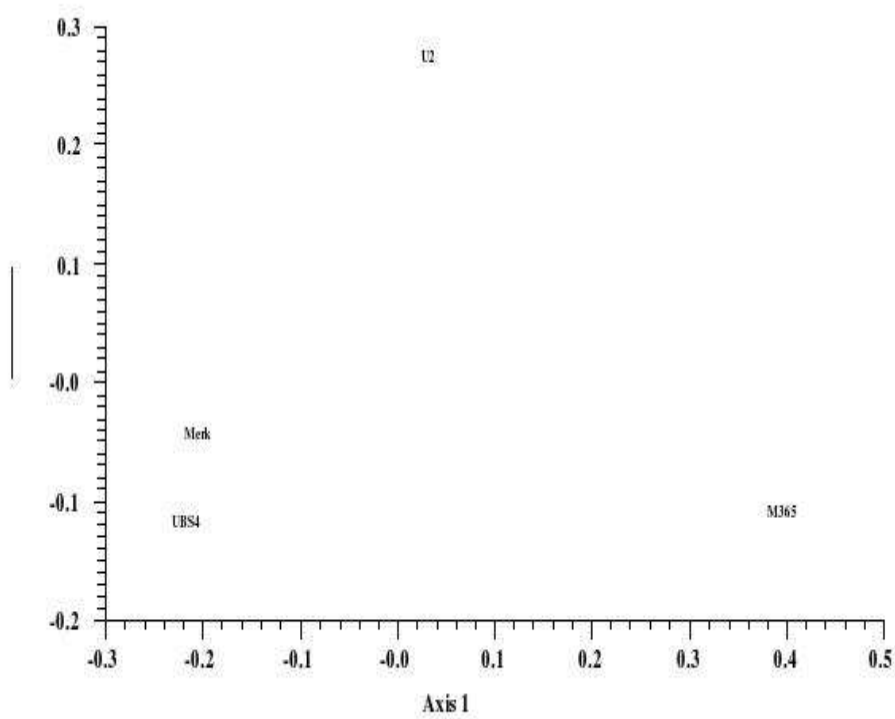
71 units; 36%, 16%

Fig. 8: Every second witness: Second cycle



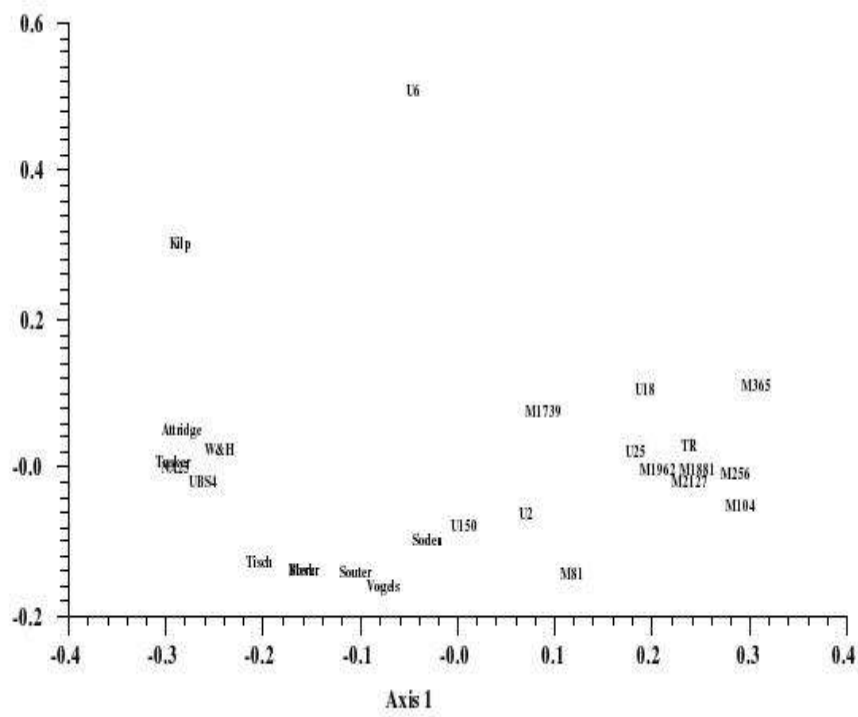
71 units; 42%, 23%

Fig. 9: Every second witness: Third cycle



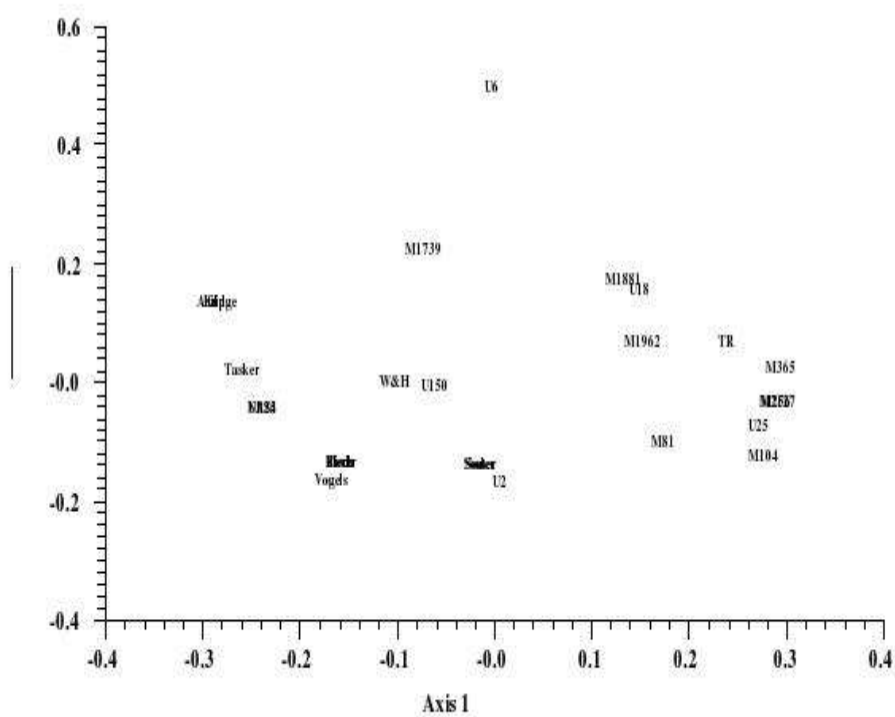
71 units; 64%, 27%

Fig. 10: Every second unit: First cycle



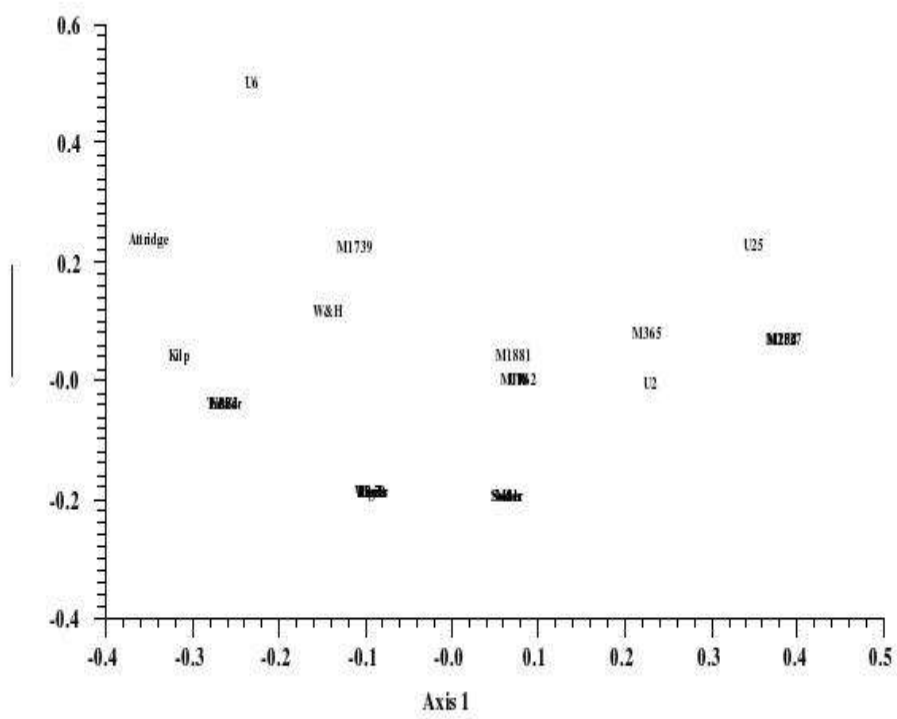
36 units; 31%, 14%

Fig. 11: Every second unit: Second cycle



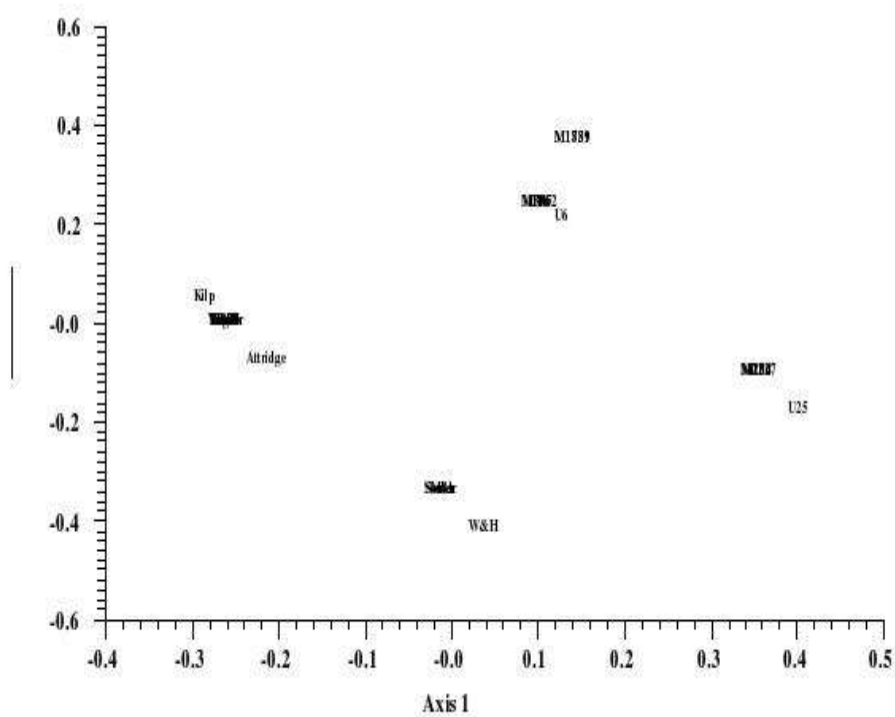
18 units; 30%, 17%

Fig. 12: Every second unit: Third cycle



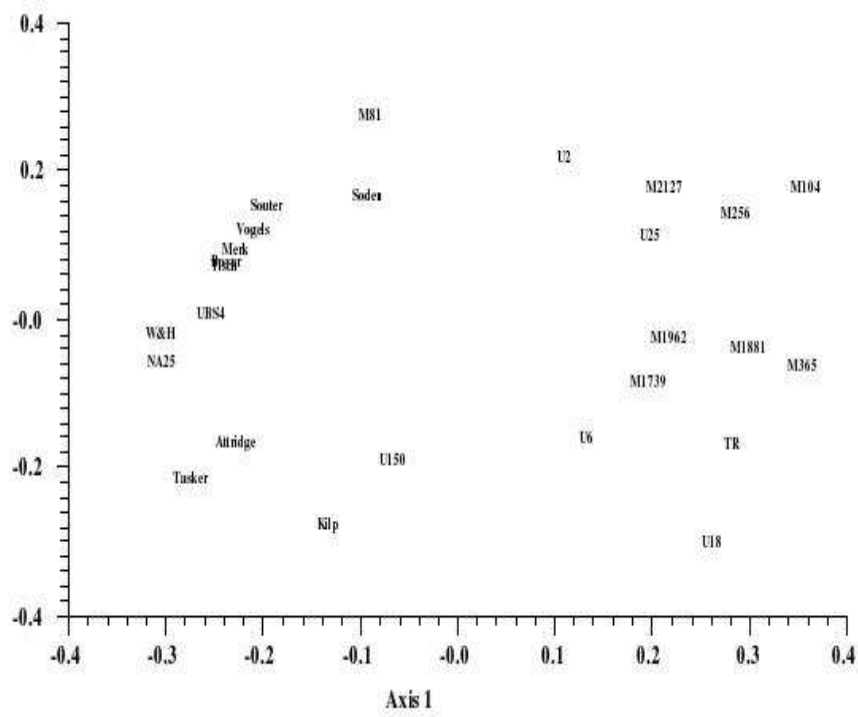
9 units; 36%, 21%

Fig. 13: Every second unit: Fourth cycle



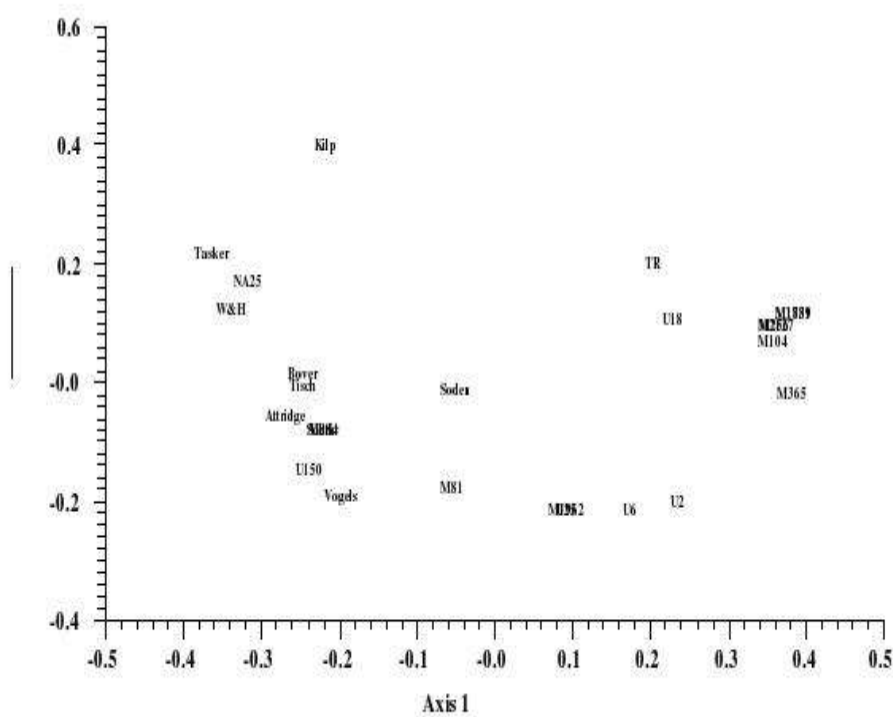
5 units; 37%, 30%

Fig. 14: First 36 units



36 units; 32%, 14%

Fig. 15: First 18 units



18 units; 45%, 16%

Fig. 16: Data matrix of random binary witnesses

	1	2	3	4	5	6	7	8	9	10
1	0	1	0	1	1	0	1	0	1	1
2	1	1	0	1	1	0	0	0	1	0
3	1	1	1	1	0	1	0	1	0	1
4	1	0	0	0	1	1	1	0	0	0
5	0	1	1	1	0	0	0	0	1	1
6	1	1	1	1	1	0	1	0	1	0
7	1	0	1	1	0	0	0	1	1	0
8	0	0	0	0	1	1	0	0	0	0
9	0	1	1	0	0	0	0	1	0	0
10	1	1	0	1	1	1	1	1	0	0
11	1	0	0	1	1	0	0	1	1	1
12	0	1	1	0	1	1	0	0	0	0
13	1	1	0	0	0	0	0	1	1	1
14	0	1	1	1	1	0	0	0	1	1
15	0	1	0	0	1	0	1	1	1	1
16	0	1	0	1	1	0	0	1	0	1
17	0	0	0	1	0	1	0	1	1	0
18	0	1	1	1	0	0	1	1	1	0
19	1	1	1	1	1	0	0	1	0	1
20	0	0	0	1	0	0	1	0	0	1
21	1	0	1	1	0	0	0	1	0	0
22	1	0	1	1	0	1	0	0	1	0
23	1	0	0	0	1	0	1	0	1	1
24	0	0	0	0	1	1	1	1	1	0
25	1	1	1	0	0	0	1	1	1	0
26	0	0	0	1	0	1	1	1	1	0

27	0	1	1	1	1	1	1	0	1	0
28	0	1	0	0	1	0	0	1	1	0
29	0	1	0	1	1	0	1	0	0	0
30	0	1	0	0	1	0	1	0	0	1

Fig. 17: Dissimilarity matrix for random binary witnesses

	1	2	3	4	5	6	7	8	9
10									
1	0.00								
2	0.60	0.00							
3	0.40	0.40	0.00						
4	0.47	0.47	0.40	0.00					
5	0.57	0.37	0.70	0.57	0.00				
6	0.50	0.70	0.50	0.57	0.53	0.00			
7	0.57	0.50	0.63	0.57	0.40	0.47	0.00		
8	0.43	0.50	0.50	0.50	0.67	0.53	0.60	0.00	
9	0.50	0.50	0.50	0.43	0.53	0.60	0.47	0.47	0.00
10	0.50	0.43	0.57	0.50	0.47	0.67	0.53	0.53	0.53
0.00									

Fig. 18: Map of random binary witnesses

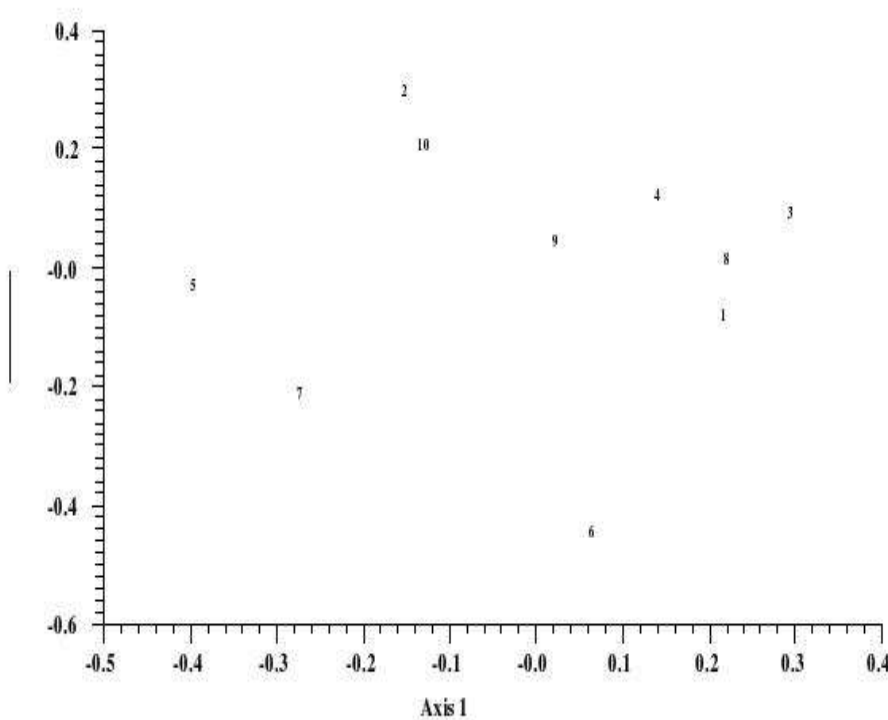


Fig. 19: Dissimilarities for random binary witnesses

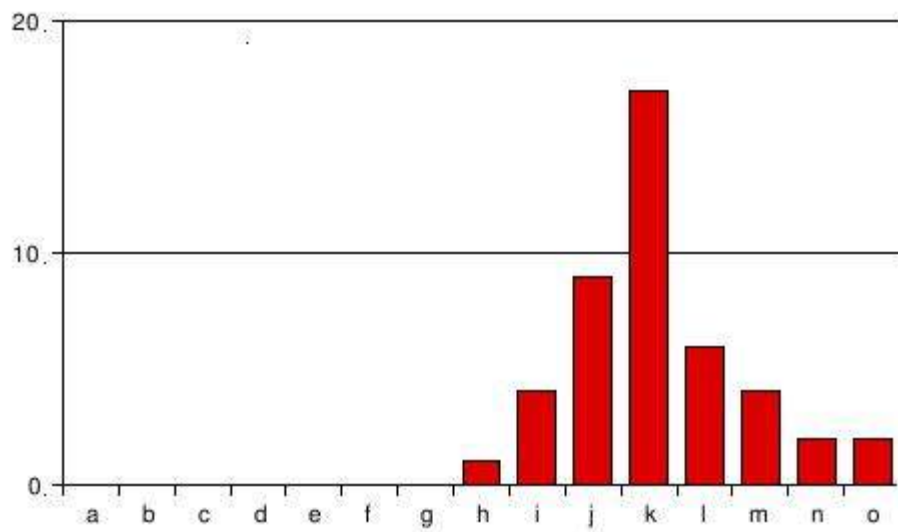


Fig. 20: Dissimilarities for primary witnesses

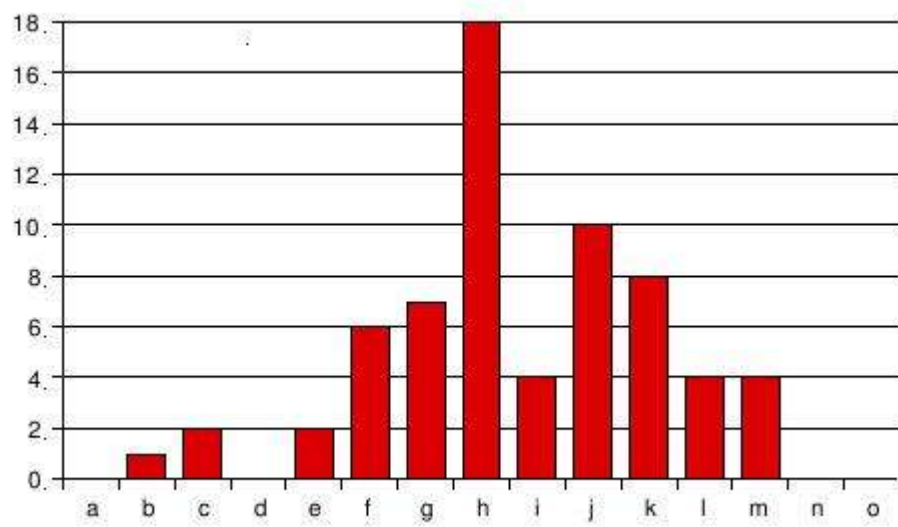


Fig. 21: Dissimilarities for sampled witnesses

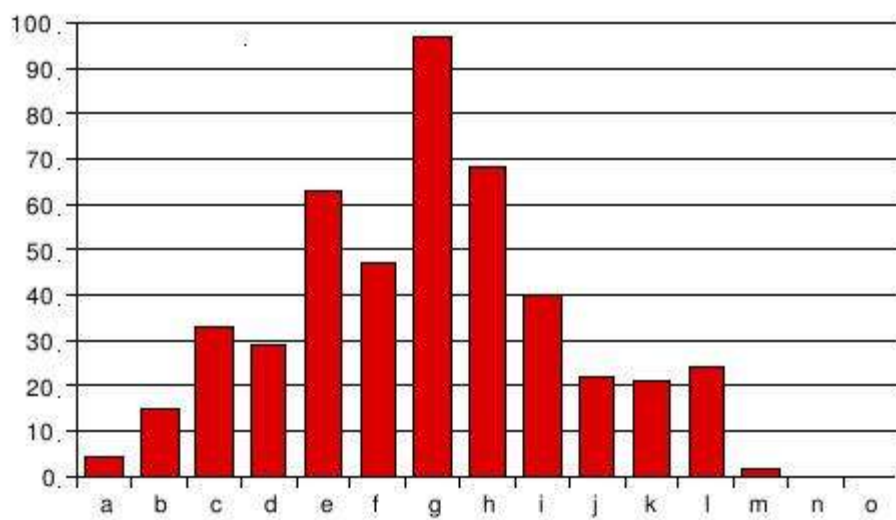


Fig. 22: Dissimilarities for multistate witnesses

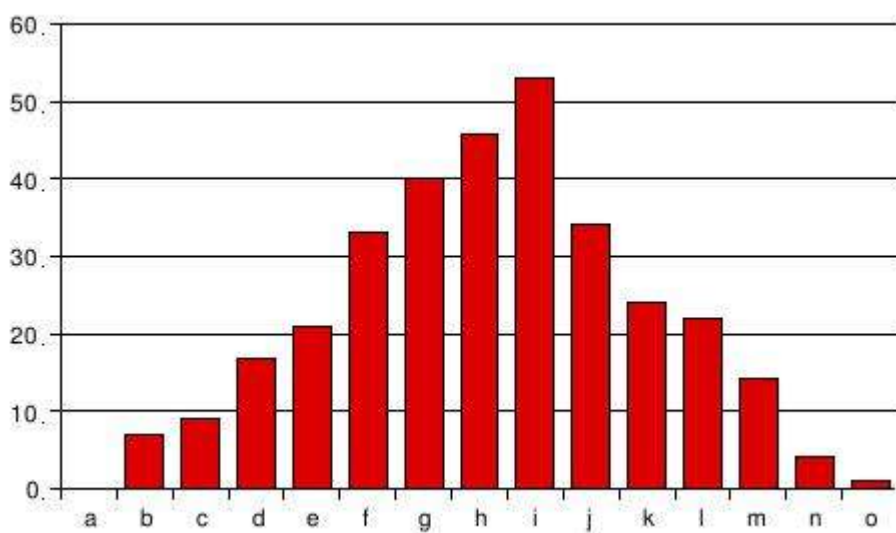


Fig. 23: Tree diagram for random binary witnesses

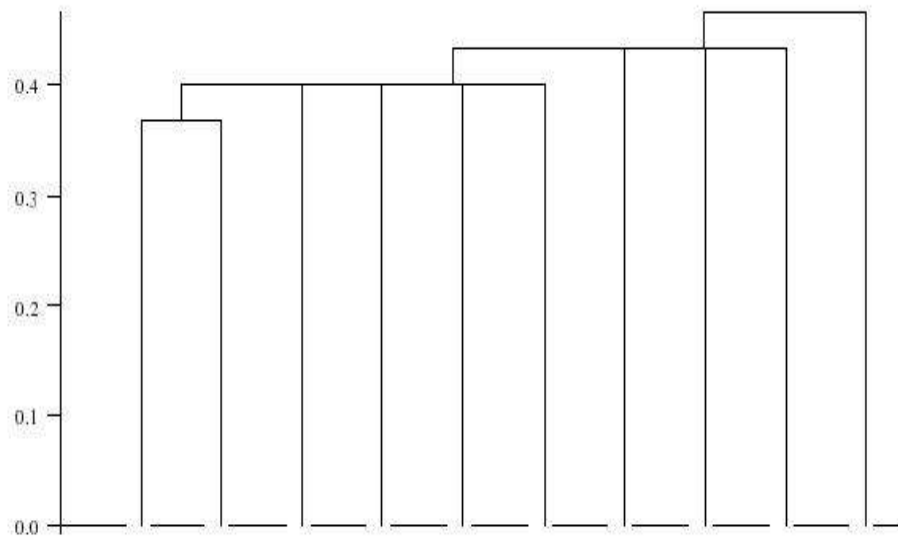


Fig. 24: Tree diagram for primary witnesses

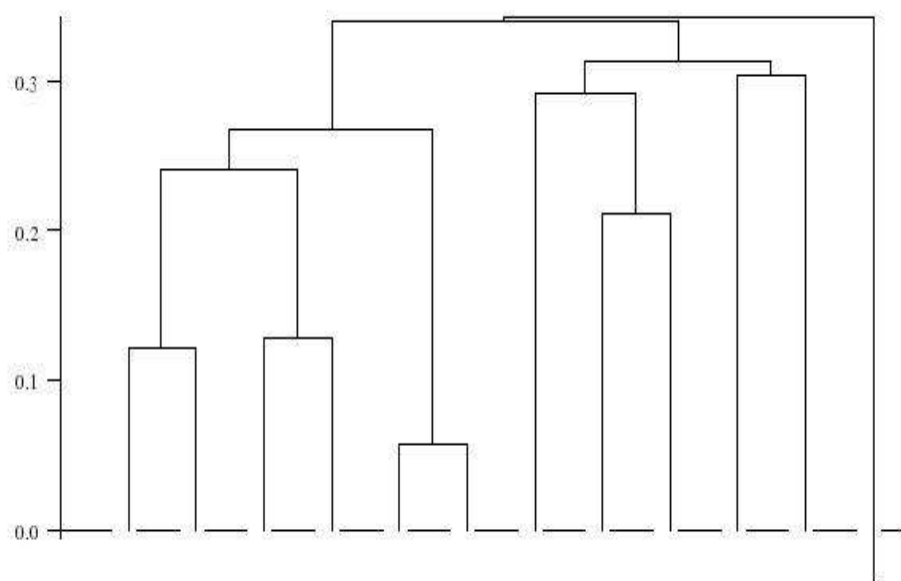


Fig. 25: Tree diagram for U3 textual witnesses

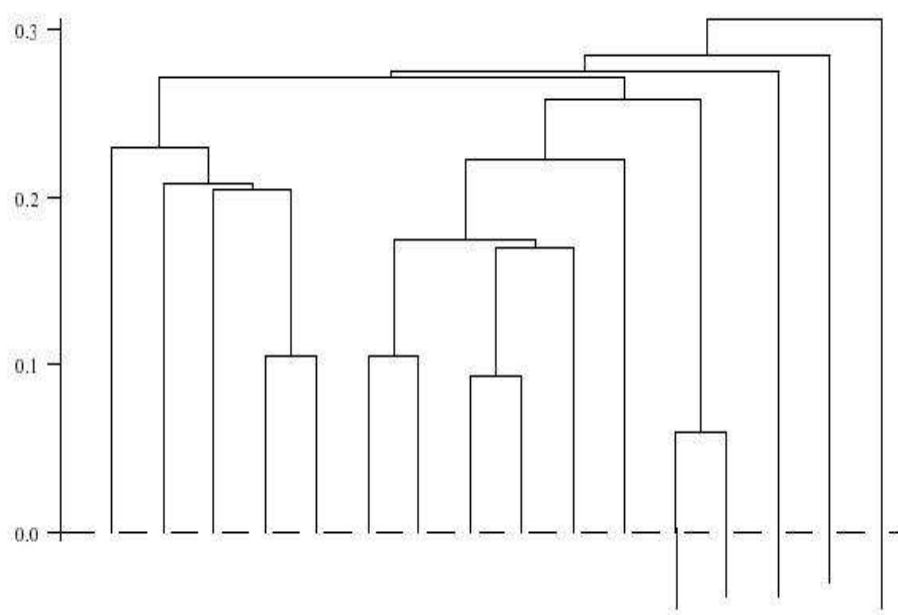


Fig. 26: Tree diagram for sampled witnesses

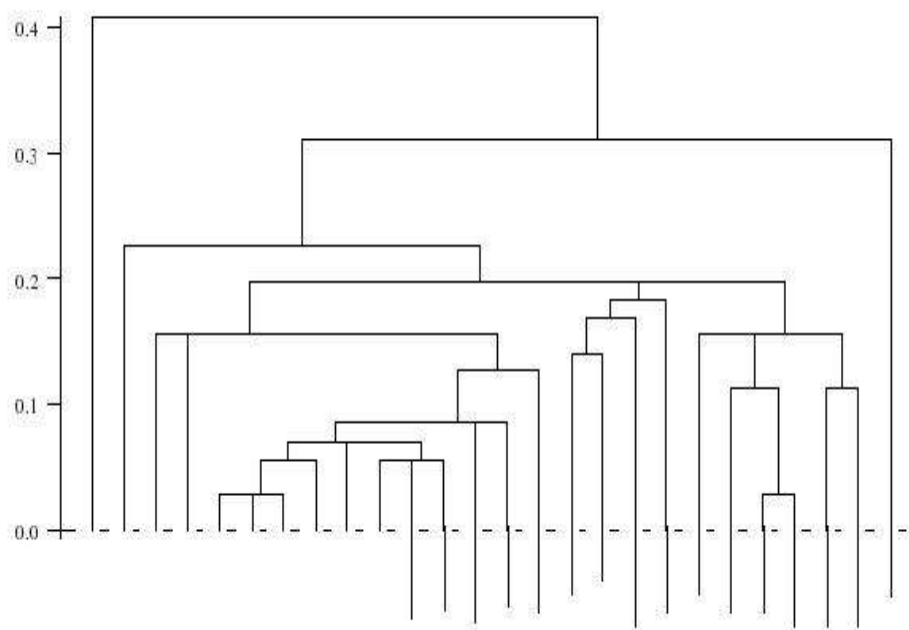


Fig. 27: Minimum spanning tree for sampled witnesses

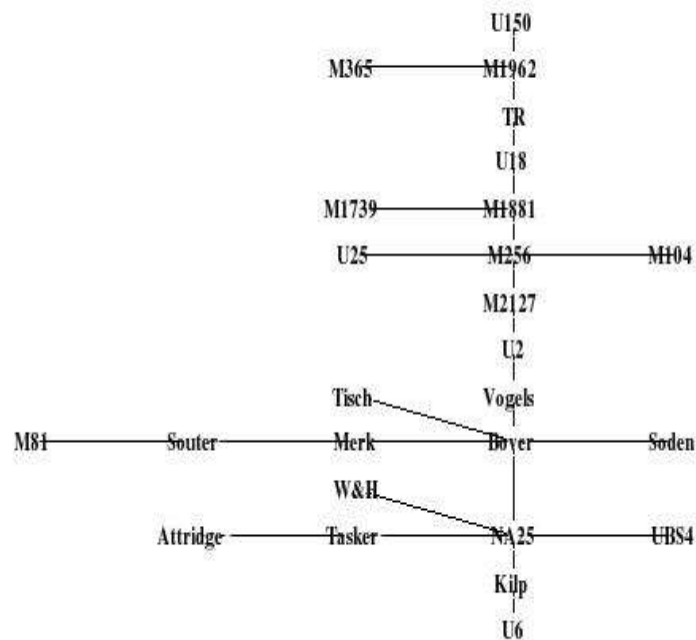


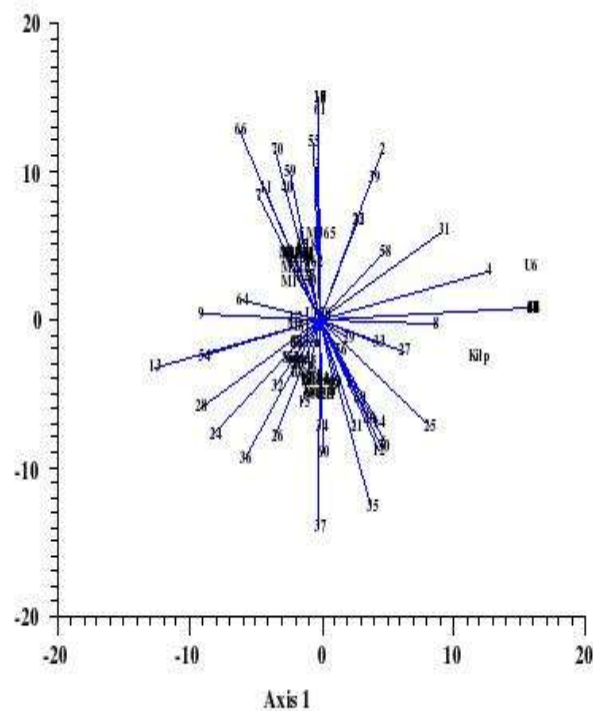
Fig. 28: Minimum spanning tree segment lengths

M256	-	M2127	0.02817
Bover	-	Merk	0.02817
Bover	-	Tisch	0.02817
Merk	-	Souter	0.05634
NA25	-	Tasker	0.05634
NA25	-	UBS4	0.05634
Attridge	-	Tasker	0.07042
Bover	-	NA25	0.07042
Bover	-	Vogels	0.08451
NA25	-	W&H	0.08451
M104	-	M256	0.11268
M1739	-	M1881	0.11268
Bover	-	Soden	0.12676
U18	-	TR	0.14085
U2	-	Vogels	0.15493
U25	-	M104	0.15493
M81	-	Souter	0.15493
M256	-	M1881	0.15493
M1962	-	TR	0.16901
M365	-	M1962	0.18310
U2	-	M2127	0.19718
U18	-	M1881	0.19718
U150	-	M1962	0.22535
Kilp	-	NA25	0.30986
U6	-	Kilp	0.40845

Fig. 29: Seriation for sampled witnesses

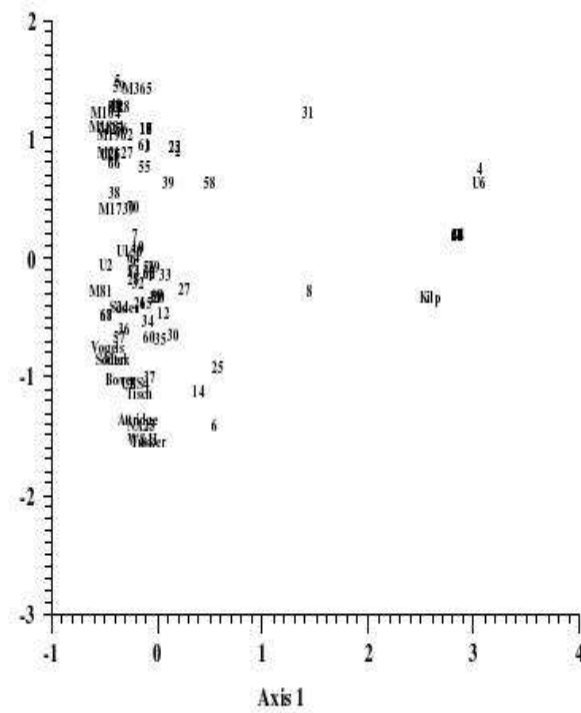
U6	44444444444444444444444444444444
M365	4 22222222223233333333344444
U18	42 122322223233333333333334
TR	421 2122222323332223333334
M1881	4222 221122222332233333333
M1962	42212 2222222322223333334
M104	423222 1211232233333333334
M256	4222121 212232232233333334
M1739	42221222 23232332232332334
M2127	422222112 223222222333334
U25	4222221232 22222322233334
U2	42332222222 3221222222224
U150	432222333323 222222232233
M81	423322222222 22122222224
Soden	4333332232222 11111122223
Vogels	433332333221221 1111112224
Souter	4332223222322111 111112214
Merk	4332223222222111 11111113
Bover	43323233322221111 1111113
UBS4	43333333222221111 111113
Tisch	433333333322211111 11113
NA25	433333333332211111 1112
Attridge	4433333332222221111 113
Tasker	443333333332222211111 13
W&H	4433333333322221111111 3
Kilp	3444444444443434433332333

Fig. 30: Principal component analysis for sampled witnesses



70 units; 25%, 20%

Fig. 31: Correspondence analysis for sampled witnesses



70 units; 28%, 20%

**Fig. 32: Canonical variates analysis for sampled witnesses:
First part**

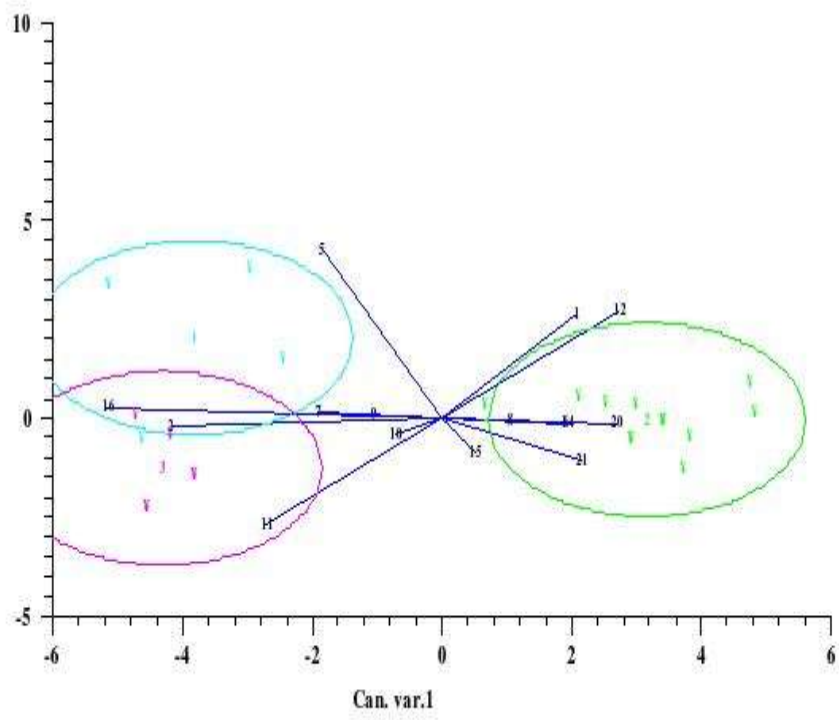


**Fig. 33: Canonical variates analysis for sampled witnesses:
Second part**

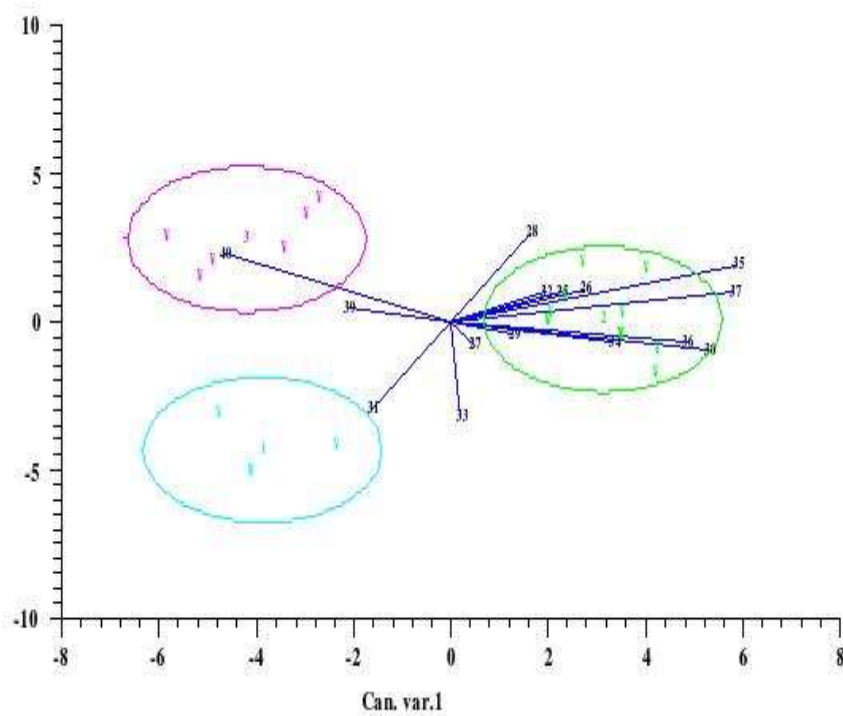
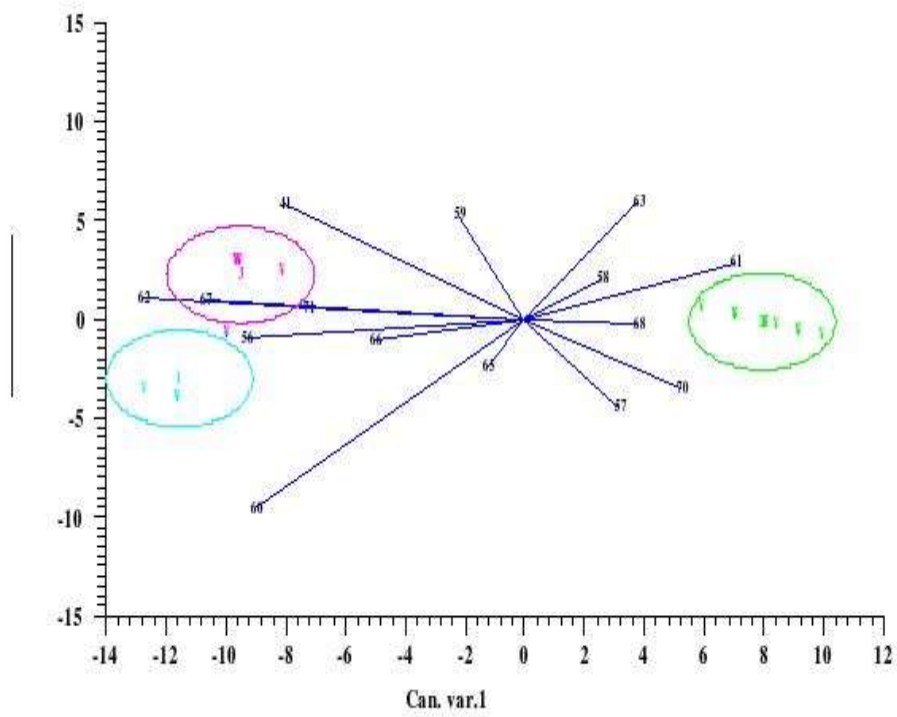


**Fig. 34: Canonical variates analysis for sampled witnesses:
Third part**



References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *The Greek New Testament*. United Bible Societies, 4th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Barbrook, Adrian C., Christopher J. Howe, Norman Blake, and Peter M. W. Robinson. 1998. 'The phylogeny of *The Canterbury Tales*'. *Nature* 394 (27 August), 839.
- Benduhn-Mertz, Annette, Gerd Mink, and Horst Bachmann. 1991. *Text und Textwert der griechischen Handschriften des Neuen Testaments*. Part 2. *Die Paulinischen Briefe*. Vol. 4. *Kolosserbrief bis Hebräerbrief*. Arbeiten zur neutestamentlichen Textforschung, 19. Ed. Kurt Aland. Berlin: Walter de Gruyter.
- Bevington, Philip R. 1969. *Data reduction and error analysis for the physical sciences*. New York: McGraw-Hill.
- Chatfield, Christopher, and Alexander J. Collins. 1980. *Introduction to multivariate analysis*. London: Chapman and Hall.
- Ehrman, Bart D. 1987. 'Methodological developments in the analysis and classification of New Testament documentary evidence'. *Novum Testamentum* 29/1, 22-45.
- Epp, Eldon Jay. 1993b. 'The significance of the papyri for determining the nature of the New Testament text in the second century: a dynamic view of textual transmission'. In *Studies in the theory and method of New Testament textual criticism*. Ed. Eldon Jay Epp and Gordon D. Fee. Studies and documents, 45. Grand Rapids: Eerdmans, 274-297.
- Farthing, Geoffrey P. 1994. 'Detailed textual stemmata by means of probability theory'. *AIBI* 4 — Bible et informatique, 214-

- Finney, T. J. 1997. 'Mapping the textual history of Hebrews'. *Revue informatique et statistique dans les sciences humaines* 33, 125-147.
- Griffith, John G. 1969. 'Numerical taxonomy and some primary manuscripts of the Gospels'. *Journal of theological studies* 20/2, 389-406.
- Griffith, John G. 1979. 'Non-stemmatic classification of manuscripts by computer methods'. *Colloques internationaux du CNRS 579 — La pratique des ordinateurs dans la critique des textes*, 74-86.
- Kvalheim, O. M., D. Apollon, and R. H. Pierce. 1988. 'A data-analytical examination of the Claremont Profile Method for classifying and evaluating manuscript evidence'. *Symbolae Osloenses* 63, 133-144.
- Metzger, Bruce M. 1992. *The text of the New Testament: its transmission, corruption, and restoration*. 3rd enlarged ed. New York: Oxford University Press.
- Mink, Gerd. 1993. 'Eine umfassende Genealogie der neutestamentlichen Überlieferung'. *New Testament studies* 39/4, 481-499.
- Moore, David S. and George P. McCabe. 1993. *Introduction to the practice of statistics*. 2nd ed. New York: W. H. Freeman.
- Podani, János. 1994. *Multivariate data analysis in ecology and systematics: a methodological guide to the SYN-TAX 5.0 package*. Ecological computations series, 6. The Hague: SPB Publishing.
- Price, James D. 1987. 'A computer aid for textual criticism'. *Grace theological journal* 8/1, 115-129.

Royse, James Ronald. 1981. 'Scribal habits in early Greek New Testament papyri'. Dissertation (ThD). Graduate Theological Union.

Spiegel, Murray R. 1982. *Theory and problems of probability and statistics*. Schaum's outline series. Asian student ed. Singapore: McGraw-Hill.

TEXTUAL DEVELOPMENT

Synopsis

This chapter focuses on textual development. The process by which scribes and correctors chose particular features for inclusion in manuscripts is treated as intentional and unintentional selection from an array of possible features at each point where variation can occur. Scribes operated according to definite rules, which suggests that a deterministic model of scribal behaviour might be possible. Such a model is unlikely to be realised, so a probabilistic approach is adopted instead. In this context, textual development can be understood as survival of features that are more likely to be selected than others. That is, those features which are fittest tend to survive through generations of copying and correction.

The dynamics of textual dissemination are discussed next. After a series of questions on Christian book production is addressed, the circumstances of book transport, survival, and recovery are investigated.

The possibility of using a computer to simulate early textual development is introduced. As well as putting forward some appropriate models that could serve as the basis of a simulation program, mention is made of potential benefits of simulation.

Finally, some possible outcomes of simulation are suggested. Among these are the development and divergence of local texts with time, and the possibility of one local text being displaced by another. A number of these outcomes have analogies in the field of population biology, which already uses computer simulation as an investigative tool.

Selection

In order to understand textual development, it is necessary to understand how features were selected during the copying

process. To copy, a scribe selects a single feature from a set of potential features at each point of the document being copied. In this context, the term 'feature' refers to a textual, spelling, or peripheral feature, and the term 'point' refers to a location within the document that can be occupied by a feature. For textual features, a point would be a segment of text that could be occupied by a number of potential readings (i.e., a variation unit); for spelling features, a point would be a location within a word that could be occupied by various letters or letter combinations; and for peripheral features, a point would be a location within or between words that could be occupied by a peripheral feature such as a line-division, punctuation mark, or *kaiv* compendium.

As a matter of convenience, the present tense will be used in the following discussion, even though the main subjects — the scribes — are no longer with us. Potential features consist of existing, imaginable, and accidental features. Accidental features are those that a scribe is capable of creating by mistake, imaginable features are ones that a scribe could plausibly imagine as being appropriate to the point in question, and existing features are those found at the corresponding places in exemplars known by the scribe. A known exemplar does not have to be physically present for a scribe to utilise its features.

Intentional and unintentional selection

Each copied feature is the product of either intentional or unintentional selection on the part of the scribe. Intentional selection occurs when a scribe chooses one from the range of existing features, or when a novel feature is consciously created. A created feature may be an adaption of existing features or an altogether new one.

Unintentional selection occurs when a scribe writes something besides what he or she intended. In a first variation on this theme, the scribe selects one feature but writes one of the rejected features. This is rare but can happen. Another variation is the conventional copying error, where the scribe writes something that is neither selected nor rejected. The result may be corrected

if it is detected. Copying errors that produce nonsense are more likely to be detected by subsequent readers than errors that make sense. For this reason, copying errors that make sense are less likely to be corrected than their nonsensical counterparts.

Rules governing selection

In general, a scribe selects the most appropriate feature from the range of potential features. What is appropriate is determined by standards, constraints, or behaviours that may be procedural, orthographical, grammatical, theological, or psychological in nature.

Procedural rules encourage a scribe to follow a definite course of action when selecting among features. For instance, a scribe may be commanded to copy the reading found in the exemplar favoured by the *diorqwthv*" when a theologically significant variation is encountered. If a scribe was not working in a scriptorium then the procedure might be to copy the feature that he or she liked best. Harmonisation would also fall into the category of procedural rules if a scribe was in the habit of selecting features supported by parallel passages. Another procedure might be to conflate alternative readings rather than to copy one or the other. This would appeal to a scribe who was wary of 'taking away' from the scriptures.

Orthographical and grammatical standards enable the scribe to select a feature according to principles that are not value-based. By contrast, theological constraints restrict what a scribe is allowed to write for fear of committing heresy. In his book, *The Orthodox corruption of scripture* (1993), Bart D. Ehrman concentrates on readings that are affected by such considerations. Whereas a scribe may be influenced by external circumstances and constraints, what is written finally depends on psychological factors. That is, a scribe's behaviour is the product of environmental conditions and individual proclivities.

Scope of selection rules

Each rule governing feature selection has an associated domain

of operation which may be geographical, temporal, structural, or a combination of these. A geographical domain might encompass the scribe alone, his or her locality, or the entire Greek-speaking world. A temporal domain might extend to the instant of copying, the active lifetime of a scribe, or a longer span of time. A structural domain embraces scribes that are part of an organisational structure such as a monastic order.

Scribal habits

As every copying act is subjectively determined, objective rules cannot provide a complete definition of scribal behaviour. Nevertheless, proclivities of individual scribes and scribes in general can be discovered by examining their manuscripts. Following the lead of Ernest C. Colwell (1965), James R. Royse (1981) set out to study singular variations (i.e., unique readings) in early Greek New Testament papyri with a view to gaining a knowledge of scribal habits. More recently, Peter M. Head has tested Royse's findings, concluding that:

our results fully support his conclusions: scribes often harmonised texts (to the immediate context and to canonical parallels)..., and they frequently transposed words into a new order. Most fundamental is the support given to the conclusion that omission is more common than addition (Head, 1990, 246).

A combination of psychological and contextual considerations can help to explain why some copying errors are more common than others, and why certain errors are more likely to occur under particular circumstances. The proclivity of a scribe to make the mental and visual error of *homoioteleuton* (i.e., omitting text between nearby words with similar endings) is due to an apparently universal human susceptibility to skip sections of text. Whether this error will happen under a particular set of circumstances is influenced by individual factors such as fatigue and distraction, as well as contextual factors such as the ease with which the scribe's focus can skip to a following word that has a similar ending to the one being copied. In a study of mistakes in P13, P. M. Head and M. Warren (1997, 467) suggest

another important cause of error:

in addition to the general issue of scribal weariness, another factor, namely the constant necessity to re-ink one's pen, provided the occasion for distraction at the level of, at the very least, eye, memory, judgement and pen.

Deterministic approach

A deterministic theory of scribal behaviour is at least as far off as a deterministic theory of human behaviour. An added difficulty in our case is that ancient scribes cannot be directly studied to obtain some of the basic information necessary for such a theory. The best that can be achieved is to study manuscripts with a view to constructing scribal profiles that will provide some guidance as to expected scribal behaviours under given circumstances. This approach is not guaranteed to describe a particular scribe's behaviour because the circumstances under which the scribe copied, which would have varied from moment to moment, are no longer known.

Probabilistic approach

By contrast, a probabilistic approach to the problem is feasible, at least in concept. I have already stated that a set of potential features exists for every point of the document being copied. The probabilistic approach associates a selection probability with each potential feature, thus producing a set of ordered pairs:

<i>Potential features</i>	F_1	F_2	...	F_n
<i>Selection probabilities</i>	$P(F_1)$	$P(F_2)$	...	P
	(F_n)			

Armed with a knowledge of scribal proclivities and conditions, a set of potential features and associated probabilities can be proposed for each point of variation. It would be wise to separate textual, spelling, and other kinds of variation from each other, resulting in a distinct set for each kind of variation at each point of variation. Usually, there will be a few features with sizable selection probabilities and many features with negligible

selection probabilities. In the typical case of a scribe copying from a corrected manuscript with an alternative reading written above the line, the reading of the manuscript and its interlinear alternative would have higher selection probabilities than other potential readings, provided that they made sense.

Once the set of potential features and associated probabilities has been obtained, a copying act can be emulated by selecting a feature at each point of variation according to the associated probabilities. The selection process chooses features in such a way that over many trials the frequency with which a feature is selected approaches its selection probability.

Estimating probabilities

Whereas it is exceedingly difficult or impossible to predict a feature's selection probability from theory, it is easy to obtain an estimate. The estimated selection probability for a potential feature is simply the relative frequency with which that feature occurs, where the relative frequency is defined as the number of witnesses with the feature divided by the total number of witnesses. Such an estimate can be obtained for a particular domain by considering only those manuscripts that come from the same domain. For instance, a feature's estimated selection probability for a particular century is equal to its relative frequency in manuscripts dated to the same century. The estimation procedure remains valid for a sample of witnesses, which is what we have in the extant New Testament manuscripts, provided that the sample does not suffer from a systematic bias.

This approach to estimating selection probabilities is not without problems. As there is only a handful of manuscripts from earlier times, errors associated with small sample sizes conspire to make estimates for the most interesting phases of textual development unreliable. If there are no early manuscripts, as happens for all regions except Egypt, direct estimates are impossible. Rather, indirect estimates must be made by recourse to later manuscripts and sources such as patristic and versional testimony. Each of these sources is unreliable in its own way. Later manuscripts do

not always behave as earlier ones. What one Church Father says is not necessarily representative of the prevailing situation. The date and provenance of a version are often uncertain. Therefore, an estimate obtained from versional evidence can have a poorly defined domain of application.

Another problem is that a feature's selection probability changes from copy to copy because scribes and their circumstances vary from copy to copy. When all copies are considered, the feature's selection probabilities form a distribution. The relative frequency of the feature's occurrence gives an estimate of the mean selection probability but says nothing of dispersion about the mean or systematic changes in the feature's popularity (e.g., a consistently increasing popularity with time). That is, a single measurement of relative frequency does not provide an adequate description of the probability distribution. (A single parameter does fully specify some distributions. However, this is the exception and not the rule.)

Survival of the fittest

To reiterate, it is assumed that there is a set of potential features for every point of the document being copied. How a scribe chooses one of the potential features is related to the rules governing selection. The actual selection process is complex and may well be impossible to emulate with a deterministic approach. Consequently, a probabilistic approach is taken whereby each potential feature is assigned a selection probability. (That is, the set is now comprised of ordered pairs.) The copying process can then be emulated by selecting consecutive potential features in such a way that more probable features will be selected more often, on average.

Supposing that one potential feature of a particular set has a greater selection probability than any other potential feature in the set, that feature will be selected more frequently than any other, on average. This feature is the most appropriate in the eyes of a typical scribe, and may therefore be labelled the 'fittest'. Its favoured status makes it the most likely to be propagated. That is,

the fittest feature is the most likely to survive the copying process. If this feature continues to enjoy its favoured status, it will be the most likely to survive many copying events and to emerge as the most popular feature in the long run.

Typical scribal attitudes can change over copying history, so that different features may be fittest at different times. When different eras are considered, the fittest feature is not necessarily the most prevalent. Rather, it is the one that exhibits the greatest rate of increase in relative frequency over the period in question. Again, the fittest feature is not necessarily the one that was found at the corresponding point of the original document (i.e., the autograph). Instead, it is the feature that is most likely to have been chosen by a typical scribe. Following this line of reasoning, the majority text is a reflection of scribal attitudes to the text. How well it approaches the original text depends on how often the feature preferred by a typical scribe coincides with the original author's preference at each point of the document.

The majority text is more representative of later scribal attitudes than earlier ones because most extant manuscripts are from the later period. A majority text could be constructed from manuscripts of an earlier period, thereby giving an indication of prevailing scribal attitudes during that time. (A majority text constructed from the earliest manuscripts may not be representative of general scribal attitudes in the corresponding era because most of these manuscripts are Egyptian.)

It is conceptually possible to identify the most likely original feature by examining the variation in relative frequencies of alternative features with time. Consider two alternative features at a particular point, F_1 and F_2 , which have the following relative frequencies among manuscripts of various eras:

	<i>2nd C.</i>	<i>3rd C.</i>	<i>4th C.</i>
F_1	0.50	0.60	0.70
F_2	0.50	0.40	0.30

Whereas the figures show that F_1 always has the same or greater prevalence relative to F_2 over the period for which evidence exists, backward extrapolation of the trend shows that F_2 would have been more prevalent at earlier dates, provided that typical scribal attitudes to these features had not changed. Accordingly, F_2 is more likely to be the original reading even though it is not the majority reading. This method of identifying the original reading looks good in theory, but the lack of early witnesses can make it unworkable in practice. This is because small sample sizes make for large uncertainties in relative frequency estimates. The confidence interval relating to the slope of each trend line is then so broad as to encompass both increase and decrease.

Some of these concepts may be illustrated by reference to a textual variation at Heb. 2.9, where the alternatives *cavriti qeou'* and *cwri;" qeou'* occur. The first reading 'has the support of the vast majority of Greek MSS as well as versional and Patristic evidence' (Elliott, 1972, 339). This does not always seem to have been the case. As Paul Garnet (1985, 321) writes, 'Origen talks as if *cwri;"* were the usual reading and *cavriti* exceptional but not unattested.' Taken together with its decreasing relative frequency, the prevalence of *cwri;" qeou'* in Origen's time suggests that it is more likely to have been the original reading than *cavriti qeou'*.

Others have reached the same conclusion using different reasoning. According to Zuntz (1953, 34), 'Harnack has shown that *cavriti* is a dogmatic correction, while the original text read *cwriivç*.' Zuntz (34-35) goes on to say that patristic evidence implies *cwri;" qeou'* was the predominant reading in the third century, that *cwriiv*" could not have arisen from *cavriti* through scribal confusion or intentional change, and that *cwriiv*" was one of the author's favourite words. Elliott (1972, 339-340) regards the anarthrous (i.e., without the article) *cavriti* as uncharacteristic of the author and of the New Testament in general. This also implies that the alternative *cwriiv*" is original. Ehrman (1993, 147)

notes that the phrase *cwri*;" *qeou*' is more troubling than the alternative and occurs less frequently in the New Testament. He concludes that 'it is extremely difficult to account for *cwri*;" *qeou*' if *cavriti qeou*' was the original reading' (148).

In the light of its apparent increase in relative frequency, *cavriti qeou*' is the fittest reading. As far as rules governing selection are concerned, there were strong theological incentives to favour *cavriti qeou*' once the two readings were in competition. As already noted, Harnack regarded this reading as a dogmatic correction. Paul Garnet (1985, 323-4) writes,

In the first two centuries after the apostles, the theological climate, in those circles where the epistle was being transmitted, was not favourable to *cwri*;"...

[It] appears likely that an orthodox scribe might change *cwri*;" to *cavriti*, shocked at the difficult expression *cwri*;" *qeou*', influenced by the early patristic emphasis on the atonement as an involvement of God himself in the human condition and perhaps even suspecting Marcionism in the phrase.

Once *cavriti* was the reading even in one manuscript, the same motives would have worked even more powerfully for its preservation in subsequent copies.

Elliott (1972, 341) thinks that *cavriti qeou*' may have become popular as a reaction to Nestorianism. (He also notes that the early attestation of *cwri*;" *qeou*' rules out the possibility that it was created by Nestorians, despite the assertions to this effect made by Theophylact and Oecumenius.) Ehrman (1993, 150) sees the preference for *cavriti qeou*' as a reaction to Gnostic misinterpretation of *cwri*;" *qeou*', concluding as follows:

It appears that scribes of the second century who recognized the heretical potential of the phrase *cwri*;" *qeou*' changed it by

making the simple substitution of the orthographically similar and altogether acceptable, if contextually less appropriate, *cavriti qeou*', thereby effecting an orthodox corruption that came to dominate the textual tradition of the New Testament.

The fittest feature and textual development

The notion of the fittest feature provides a basis for understanding textual development. The fittest feature is the one most likely to be selected under a given set of conditions — the one that is best adapted to its habitat. Internal conditions, such as a scribe's psychology, and external conditions, such as the scribe's temporal, geographical, and structural situation, are both important in determining the fittest feature.

Where intentional selection is concerned, the fittest feature is the one that best satisfies the scribe's selection rules. In the case of unintentional selection, the fittest feature is the error most likely to be made in view of the scribe's situation, textual context, and characteristic copying faults. Textual development can then be understood as a process of selecting the fittest feature at each point where a scribe or corrector thinks that an alternative feature may be appropriate, as well as at each point where a mistake is liable to be made.

Dissemination of manuscripts

The process by which Greek New Testament manuscripts were dispersed throughout the Greco-Roman world is another important aspect of textual development. I shall concentrate on what might be called the 'papyrus age' of Christian manuscript production: the time from about 80 to 300 CE when manuscripts were usually copied on papyrus. As Streeter points out, Christian manuscripts of this era were normally cheap copies made by amateurs, their obvious errors were probably corrected by conjecture or by comparison with local copies, and newly created readings were usually reproduced in subsequent copies. What is more, the first copy to reach one region probably differed from the first copies to reach other regions:

So long as books were copied by hand, no two copies could be *exactly* the same; every copy included certain scribal errors. In the scriptoria of the great libraries it was customary in antiquity for a corrector, *diorqwthv*", to go over a MS., sometimes with the original from which it was copied, more often, apparently, with another copy. The most obvious mistakes, including accidental omissions, would thus to a large extent be rectified. But this is unlikely to have been done in the earliest MSS. of the Gospels, which would be cheap copies and often made by amateur scribes. In that case an error which made nonsense or spoilt the grammar of a sentence would be subsequently corrected by the owner of the book — probably, from lack of another copy, by conjecture. If, however, the error was one which left a reading which still made sense, it would be likely to escape notice altogether. In either case the new reading would be reproduced by all subsequent scribes who used this copy as an exemplar. Now as soon as there were numerous copies of a book in circulation in the same area, one copy would constantly be corrected by another, and thus within that area a general standard of text would be preserved. But what we have to consider is that it is unlikely that the errors in the first copy of the Gospel of John, for example, which reached Rome would be the same as those in the first copy which came to Alexandria; and as each of these would become the parent of most other copies used in those respective cities, there would, from the very beginning, be some difference between the local texts of Rome and Alexandria (Streeter, 1925, 35).

The following discussion treats the dissemination process under the headings of production, transport, survival, and recovery. Frequent references are made to Harry Y. Gamble's *Books and readers in the early church*, and to a review by Eldon Jay Epp (1997) that responds to certain issues raised in Gamble's book.

Production

The aim of this section is to investigate the why, what, where, when, and how of Christian book production. My intention is not

to produce an exhaustive survey of all circumstances, but to concentrate on issues that relate to the dynamics of production. The question of how many Christian books were in use at any one time will be addressed as well.

Why were Christian manuscripts produced?

Christian manuscripts were an essential part of Christian identity from the beginning (Gamble, 1995, 141). They were produced to satisfy demand which came primarily from the Christian community, although it is conceivable that some non-Christians would require copies as well (40, 112-113). As a result, wherever there was a Christian community, there also were Christian manuscripts. Any particular Christian community would have to exceed a certain size before it would have the resources necessary to acquire and use a manuscript. Economic factors do not seem to have been particularly restrictive (231), but literacy was. Gamble estimates that the literacy rate among Christians was about 10 percent (5), and 'probably never exceeded 15-20 percent in the first few centuries' (231). Epp (1997, 29) wonders whether these figures might be too conservative:

The vast breadth but also depth in classical authors found in either the second or the third century in Oxyrhynchus suggests at least a questioning of the 10% to 20% average literacy rate for the entire Greco-Roman world that Gamble accepts from William Harris.

Taking a rate of 15 percent as a compromise, the expected size of a Christian community with one literate member would therefore be about seven (i.e., $1 / 0.15$).

What were the characteristics of Christian manuscripts?

This question will be treated under the headings of format, contents, and scope:

(1) Format

The codex seems to have been the normal format for Christian manuscripts since the earliest times. Various proposals have been

advanced to explain why Christians are the first identifiable group to have adopted the codex. The following summary of these views is taken from a survey that Epp (1997, 17-26) provides in the review mentioned before. C. H. Roberts suggested that the Gospel of Mark was originally written on a parchment codex, thereby setting the pattern for subsequent Christian books. T. C. Skeat later attributed the adoption of the codex to the fact that standard sized rolls were physically incapable of holding all four Gospels. (More recently, Skeat (1997) has presented a persuasive argument in support of P4, P64, and P67 being fragments of a late second century codex of the four Gospels.) Gamble also suggests that the physical limitation of standard sized rolls was the catalyst for Christians adopting the codex, but he contends that the first Christian codices were made to hold the Pauline letters rather than the four Gospels. (The Pauline letters would have taken far less space than the four Gospels. They could be accommodated in a single-quire codex, as demonstrated by P46.)

Taking a different approach, Michael McCormick notes that ancient doctors and teachers preferred to use 'modest-sized' codices that were convenient for travel, and that itinerant evangelists adopted the codex for the same reasons of convenience. (Epp points out that nearly all of the early Christian papyri conform to the dimensions of these modest-sized codices.) Graham N. Stanton takes a similar line, suggesting that Christian scribes prepared pocket-sized codices for missionaries. These held single Gospels at first and subsequently developed to hold more books. As well as being convenient, the novel format provided a means of distinguishing Christian books from those of Judaism and the secular world.

During his survey, Epp makes his own contribution to theories of why Christians adopted the codex. He agrees that portability was an important factor, but does not attempt to discern the contents of the earliest Christian codices:

My own answer as to what might have been between the covers

of a Christian traveler's codex would be quite muted; I would simply postulate that somewhere in the first century and a half of Christianity, some traveling leader (or leaders) utilized the codex for carrying writings important to such a person in the early Christian mission — whatever those writings might have been. In a time of relatively few personal possessions, a respected visitor's "props" (so to speak) would be strikingly visible to the congregation visited and doubtless would be readily imitated — since papyrus was relatively plentiful and inexpensive (Epp, 1997, 21).

Not all Christian books were codices, and some early New Testament papyri such as P12, P13, P18, and P22 are rolls. Some of these particular manuscripts are exceptional, having been written on reused papyrus or on the back of existing rolls (Epp, 1997, 22).

(2) Contents

Which books did Christian codices contain? There were many Christian books, but not all were equally popular. Justin Martyr provided the following glimpse of mid-second century Christian practice:

On the day which is called the day of the sun there is an assembly of all those who live in the towns or in the country, and the memoirs of the apostles or the writings of the prophets are read for as long as time permits (quoted in Gamble, 1995, 151).

What Justin calls 'the prophets' were probably extracts from the Septuagint. Stanton (1997, 330) regards the meaning of the 'memoirs of apostles' as no less clear:

In the preceding chapter the reader is told explicitly that [the memoirs] are 'the gospels' (1 *Apol.* 66), the first Christian occurrence of the plural. This is not a later gloss, for, as Luise Abramowski has shown, Justin does add similar explanatory phrases for his readers.

As Gamble (1995, 215) points out, the variety of Christian literature that was in circulation by the end of the second century compelled Christians to ask which books should be read in a church. This question was answered by reference to common practice:

Liturgical reading was the concrete setting from which texts acquired theological authority, and in which that authority took effect. In this light it is not surprising that when Eusebius in the early fourth century took stock of "the writings of the new covenant," that is, Christian texts that had scriptural authority, he considered chiefly whether they had been used by earlier ecclesiastical writers and whether they had been publicly read ... in all or most churches (Gamble, 1995, 216).

That is, for the most part, the canon is a list of the most widely read New Testament writings. There are notable exceptions to this rule: the letters of Clement and the *Shepherd of Hermas* were commonly read but did not become canonical.

Fig. 1 shows which canonical New Testament books are represented by papyrus codices dated up to and including the turn of the fourth century. Judging by this sample, the Gospels of John and Matthew were the most popular New Testament books among early Christians. Luke's Gospel and the Acts of the Apostles follow with approximately equal representation. The next most popular books seem to have been individual Pauline letters, individual Catholic letters, and Revelation, roughly in that order. Surprisingly, Mark's Gospel is represented in only one of the manuscripts.

In many ways, to ask which books were likely to be contained in an early Christian codex is to ask which books a typical early Christian community found most desirable to have. As far as the canonical New Testament books are concerned, each one enjoyed a certain popularity that is reflected by its frequency of occurrence in fig. 1. Accordingly, it can be said that a Gospel or collection of Gospels would be the first preference among typical

early Christian communities, assuming that Egyptian Christians were typical. Although other parts of the New Testament were also popular, their acquisition would not have been as urgent. The relative frequency with which a book occurs among New Testament manuscripts of a particular time and place is an estimate of that book's probability of being acquired by a Christian community of the same time and place.

(3) Scope

Did early Christian codices contain collections or were they comprised of individual works? According to Zuntz (1953, 14), the Pauline letters were gathered together as early as 100 CE and circulated as a collection from that time onwards. Assuming that the codex technology of 100 CE was sufficiently advanced for a single codex (whether of single- or multiple-quire construction) to contain all of the Pauline letters, any one of the four Gospels would have fitted into a single codex as well. Fig. 2 shows the relative sizes of New Testament books and collections as compared with the Pauline letters (including Hebrews). A collection of all four Gospels would have required nearly twice the space, while a collection of the canonical New Testament books would have taken nearly four times the space required for the Pauline letters.

Fig. 3 plots the relative sizes of various New Testament books and collections versus estimated publication dates. The first point relates to the Gospel of Paul's travelling companion Luke, the autograph of which I have taken to be dated around 60 CE. (This is early by the standards of modern scholarship, but not impossible.) The next point relates to early collections of the Pauline letters, which Zuntz dates to about 100 CE (although he does not include Hebrews at this point). The dates associated with the other two points require some explanation.

I have estimated the date of the first single codex collections of all four Gospels according to the following reasoning. Stanton (1997, 340) writes that 'The four-gospel codex strongly encouraged acceptance of the fourfold Gospel, and vice versa'.

This is in harmony with the idea of canon as formalisation of commonly accepted practice. Presumably, collections of the four Gospels had been circulating for some time before Irenaeus mounted his defence of the fourfold Gospel around 180 CE. As Kenyon (1933, 13) wrote,

When ... Irenaeus at the end of the second century writes of the four Gospels as the divinely provided evidence of Christianity, and the number four as almost axiomatic, it is now possible to believe that he may have been accustomed to the sight of volumes in which all four were contained.

Allowing a couple of decades for the four-gospel codex to become established, I arrive at a date of about 160 CE for the first of these codices. Stanton (1997, 340) gives a slightly earlier estimate of 'shortly before the middle of the second century'. Another piece of evidence that bears upon this date is provided by the extant papyri. T. C. Skeat (1997) asks whether P4, P64, and P67 might be fragments of our earliest extant codex of the four Gospels, and answers in the affirmative. These fragments are dated to the late second century.

No examples of papyrus codices containing all of the canonical New Testament books are known, but this does not imply that they never existed. Fragments or even complete books may once have been part of such collections. The advent of multiple quire parchment codices brought about a quantum leap in capacity, just as papyrus codices had done in the first century. By the early fourth century, single volume copies of the entire Bible (i.e., pandects) were being produced. This breakthrough may have shifted attention away from papyrus as the preferred writing medium, but not completely. Egyptian Christians continued to use papyrus for New Testament books until the seventh century, so it is conceivable that papyrus codices with ever increasing capacities continued to be produced.

Assuming that they did in fact exist, the date of the first single-codex collections of the canonical New Testament books can be

estimated in the same way as the date of the first four-gospel collections. Taking the 367 CE date of Athanasius' canon list as a starting point, and allowing two decades for such codices to become an established norm, a date of 350 CE is obtained.

Could the New Testament canon have been influenced by the technical development of the codex? Even though the date estimates are highly speculative, it is of more than passing interest to note that the resultant points lie along a straight line. Starting with a pool of individual Gospels, letters, and books, collections of increasing size were compiled over time. The Pauline letters were among the first to be collected into single-volume papyrus codices, followed by the four Gospels and, perhaps, the entire New Testament. The dates at which the collections are estimated to have appeared correspond to the sizes of the collections. Apparently, the capacity of papyrus codices was increasing in a linear fashion, possibly driven by those who wanted to incorporate more and more books into single volumes. Once the required capacity was reached, collections of the desired works could be produced.

An urge to combine the four Gospels into a single volume might have stood behind Tatian's decision to create his Gospel harmony. Would he have bothered if codices could contain all four Gospels at the time he began this work? Supposing that the Diatessaron was a condensed version of the four Gospels made necessary by insufficient codex capacity, we can say that codices could not fit all four Gospels when Tatian wrote around 150-160 CE. This implies a lower time-limit for the earliest codices of the four Gospels that is just prior to my estimated date for their appearance.

Luke's Gospel may represent a transition from roll to codex use by early Christians. The convenience of the codex format for missionary activity would not have been lost on Luke and his associates, who may have been interested in experimenting with a format which had the potential to include more text than the standard roll. After all, Luke knew what it was like to run out of

space. As Stanton (1997, 334) writes,

It is generally accepted that Luke and Acts were originally written on two separate rolls: they could not have been squeezed onto one roll; the short Preface to Acts with its rededication to Theophilus was a conventional way of introducing the second roll of a single work.

In order to fit the straight line relationship of fig. 3 exactly, Mark's Gospel would have to be dated to about 35 CE, which is too early by most estimates. Nevertheless, if C. H. Roberts was right to think of this Gospel as the first Christian codex, its smaller size and earlier date relative to a Gospel such as Luke's is consistent with the trend of decreasing size with earlier date. A point corresponding to the Gospel of John would be nowhere near the trend line, given that the fourth Gospel is thought to be dated after the synoptics. This does not mean that the observed trend is spurious: its points relate to maximum possible capacity and are therefore not influenced by works that easily would have been accommodated by contemporary codices.

Returning to fig. 1, papyri that are known to be collections of New Testament books are marked with bold sigla. It is possible that all of the listed papyri are from collections, but their fragmentary nature often prevents us from being sure. If each papyrus is considered to represent a collection of the Gospels, the Pauline letters, or the catholic letters, then there are eighteen separate representatives of the four Gospels, eleven of the Pauline letters, and five of the catholic letters. Epp (1997, 23) arrives at similar results in his survey of New Testament codices, which covers the same period of time as my survey:

Subtracting the four fragments from rolls and thereby, for our present purpose, counting only the forty-four earliest codices, twenty (or 45.5%) contain gospels (including 0212, the Diatessaron parchment), twelve (or 27.5%) contain Pauline letters, six (or 13.5%) contain the Acts (plus two others that also have gospel portions), five (11.5%) have catholic epistles, one

(2%) has the Apocalypse of John, and Hebrews is found along with Pauline letters in P46.

The agreement is not surprising as both surveys use substantially the same data, except that Epp counts early parchments as well.

Where were Christian books reproduced?

In order to simplify matters, I will concentrate on individual Christian books rather than manuscripts from now on. This allows each book to be treated separately. By knowing which books were likely to be found in early Christian manuscripts, findings that relate to individual books can be generalised to manuscripts.

As a general rule, a Christian book could only be reproduced where copies of the same book already existed. If a Christian community could not get hold of an exemplar, it would have to arrange for a copy to be made where an exemplar existed, or to borrow the exemplar for the purpose of making a copy. Neither of these tasks would have been difficult given the freedom of travel and pervasive Christian social network of the time:

The dynamism of life in the Greco-Roman world — even in the outlying areas of Egypt (where most of the NT papyri were discovered) — permitted relatively easy travel and rather free transmission of letters and documents, so that the earliest NT papyri — though they have survived accidentally and randomly — are generally representative of the earliest NT texts used by the Christianity of the time in all parts of the Greco-Roman world (Epp, 1993b, 295).

In such an environment, it would be a straightforward matter to request a copy of a Christian book then to have the copy transported to the place where it was required. Alternatively, an itinerant evangelist could carry a spare copy of a book to leave with a community he or she was about to visit.

Whereas the earliest copies of a book to reach a place would be

from other parts of the Greco-Roman world, there would be little demand for exotic exemplars once local copies became abundant. According to Zipf's principle of least effort (1949, 543), 'each individual will adopt a course of action that will involve the expenditure of the probably least average of his work'. Accordingly, early Christian communities would not normally bother to obtain books from distant places if copies were available nearby.

When were Christian books reproduced?

A Christian book would be reproduced whenever a Christian community had need of one, either for its own use or for the use of others. Pamphilus is a good example of an early Christian who was in the habit of giving books away, as the following quote from Eusebius shows:

What lover of books was there who did not find a friend in Pamphilus? If he knew any who were in want of the necessities of life, he helped them to the full extent of his power. He would not only lend copies of the Scriptures to read, but would give them most readily, and not only to men, but to women too if he saw that they were given to reading. He therefore kept a store of manuscripts ... so that he might be able to give them to those who wished for them whenever occasion demanded (quoted in Gamble, 1995, 158).

Books would be reproduced to supply demand from an expanding Christian population, or to replace books lost through age, wear and tear, or misadventure. As already mentioned, there may have been demand from non-Christians as well, but this probably would have been negligible by comparison with Christian demand.

I have also noted that cost does not seem to have been an issue. On this point, Gamble (1995, 231) writes:

we have observed that as a rule Christian literature was not produced or distributed through the commercial book trade. Like

most other literature, it had to be acquired through private transcription, and that required locating the text and gaining permission to copy it. [Another] factor, cost, was probably the least important. The only expense lay in the cost of materials and the services of a scribe, and economies could be obtained by copying the text on the back of an existing roll ... or in an erased roll or codex ..., or by transcribing the text personally instead of employing a professional scribe. Moreover, in some Christian centers books could be had more or less for the asking: Pamphilus, on the evidence of Eusebius as cited by Jerome, not only lent books but readily gave them away, and he kept a stock of manuscripts for the purpose.

It is possible that tithing was practised among early Christians. Whereas the nominal rate is ten percent, it is probably more realistic to assume that a typical early Christian would have given at a lesser rate, perhaps of five percent. A church of about twenty members would then raise an average individual's income. Consequently, the cost of having a book copied would be well within the church's means. Papyrus was not expensive:

the prices which have come down to us suggest that a roll of papyrus was by no means an expensive commodity; and in any case the lavish manner in which papyrus was often used, with wide margins and large unwritten areas, shows that the cost of the material was never a limiting factor (Skeat, 1969, 59).

Neither was it expensive to have a book copied: the amount that a scribe of the times was paid to copy an average sized Greek play was approximately equivalent to the basic bread-ration, one chicken, or half a tunic (Prof. Peter J. Parsons, Oxford summer school of papyrology, 1997). In any case, scribal costs are probably irrelevant because a literate member of the church could be asked to transcribe the desired book.

As the chief constraint on Christian book production was the extent of demand from the Christian community, the frequency of Christian book production at any one time and place can be

related to the size of the Christian population in the same time and place. Neglecting the influx and outflow of Christian books from a region (which would, on average, have been equal), demand can be partitioned into first-time acquisition and replacement, both of which can be further subdivided into two components corresponding to books owned by Christian communities and books owned by individuals.

The number of first-time acquisitions in a particular period should have varied according to the net Christian population growth over the same period, provided that the population was continually increasing. The number of replacements required would have varied according to the number of books already in existence and their average life-spans.

A single, communally-owned book could serve the needs of an entire Christian community, whereas an individually-owned book was only likely to be used by the literate owner and his or her immediate household. Despite the supposedly low literacy rate, there are still references to the private use of books among early Christians (Gamble, 1995, 231-4). The ratio of early New Testament opisthographs to codices may provide a means of estimating the level of private ownership in the early Christian community. Gamble (236) writes:

Most opisthographic manuscripts were either school texts or private copies made by or for persons of limited means. Not many early Christian texts were transcribed on rolls rather than in codices, but of those that were, most are opisthographs... Such texts were probably private copies made for personal use.

It was noted before that P12, P13, P18, and P22 are rolls. One of them, P12, is but an isolated verse and can hardly be regarded as a copy of a Christian book. If the other three are considered to be private copies and the forty codices listed in fig. 1 are considered to be church copies then the ratio of individual to communal ownership is 3/40 (i.e., 7.5%). Judging by this estimate, individual ownership was not of much consequence to the overall

demand for Christian books during the period in question. This estimate should be regarded with caution because some of these rolls could have belonged to churches and some of the codices could have belonged to individuals.

How were Christian books reproduced?

Christians were particularly concerned with copying their own literature. Polycarp arranged for letters that he and the church at Smyrna received from Ignatius to be copied and sent to the church at Philippi around 100 CE (Gamble, 1995, 110). Presumably, the Pauline letters had been gathered into collections around this time by the same process of one church requesting copies of letters known to have been addressed to other churches.

Like most other literature of the time, early Christian books were copied privately rather than commercially (Gamble, 1995, 231). Instead of employing a scribe, literate members of a Christian community could copy any book that was required. This in-house copying activity seems to have been the normal mode of Christian book reproduction, at least until the advent of Christian scriptoria proper. Gamble (1995, 121) writes,

It is difficult to determine just when Christian scriptoria came into existence. The problem is partly of definition, partly of evidence. If we think of a scriptorium as simply a writing center where texts were copied by more than a single scribe, then any of the larger Christian communities, such as Antioch or Rome, may have already had scriptoria in the early second century, and in view of Polycarp's activity something of the kind can be imagined for Smyrna. If we think instead of a scriptorium as being more structured, operating, for example, in a specially designed and designated location; employing particular methods of transcription; producing certain types of manuscripts; or multiplying copies on a significant scale, then it becomes more difficult to imagine that such institutions developed at an early date.

Early in the third century, Origen had at his disposal a team of

stenographers, copyists, and female calligraphers who were supported by his patron Ambrose (Gamble, 1995, 120). Many of Origen's works and, possibly, much of his personal library were collected into the library at Caesarea by Pamphilus (155). Any significant library would be expected to have an associated scriptorium (121), and the stockpile of manuscripts that Pamphilus kept for those interested in reading Christian books points to the library at Caesarea having a scriptorium that was operating by the end of the third century. Constantine's order of fifty Bibles from Eusebius confirms that the scriptorium was operating early in the fourth century (121). It must have had an impressive capacity for reproducing books, even if Constantine's order was only for Gospels rather than entire Bibles (see Gamble, 1995, 159).

There is only indirect evidence for Christian scriptoria in earlier times. Some regard the New Testament papyri P66 and P46, which are dated around 200 CE, as the products of scriptoria. With respect to P66, Ernest C. Colwell (1965, 382) wrote:

P66 seems to reflect a scribe working with the intention of making a good copy, falling into careless errors, particularly the error of dropping a letter, syllable, a word, or even a phrase where it is doubled, but also under the control of some other person, or a second standard, so that the corrections which are made are usually corrections to a reading read by a number of other witnesses. Nine out of ten of the nonsense readings are corrected, and two out of three of all his singular readings. In short, P66 gives the impression of being the product of a scriptorium, i.e. a publishing house. It shows the supervision of a foreman, or of a scribe turned proofreader.

Zuntz must have thought P46 was copied in a scriptorium because he describes its second hand as 'the hand of the *ex officio* corrector who, still in the scriptorium, applied the finishing touches to the work of the scribe' (1953, 253). Later, he writes, 'The conclusion is inescapable that already in the latter half of the second century the Alexandrian bishopric possessed a

scriptorium' (273).

There is no certainty that there were scriptoria at this time. As well as papyri which seem to bear the marks of scriptoria, there are others such as P45 which do not (see Colwell, 1965, 382). Also, the fact that a manuscript has been corrected does not necessarily mean that it was copied in a scriptorium: corrections may have been the result of a general habit of comparing manuscripts whenever the chance arose, or of correcting manuscripts whenever they were transferred from one church to another. Nevertheless, the Alands' view that 'there were no scriptoria ... before A.D. 200 at the earliest' is probably too emphatic. On this subject, Epp (1997, 25) has the following to say:

How much ... do we know about Christian scriptoria in this early period? Gamble ... skilfully pulls together the evidence and makes perhaps the best possible case for Christian scriptoria in the second century, though one based — of necessity — on inference and speculation, and C. H. Roberts inferred from the large quantity of Christian texts, including an autograph, found at Oxyrhynchus that a Christian scriptorium there in the third century or even the late second is "not unlikely".

To bring these various strands together, it is generally agreed that Christian books were copied privately by literate members of early Christian communities. Some of these communities, such as the one at Smyrna around 100 CE, were particularly concerned with collecting and distributing Christian literature. Others were content to make copies for their own needs alone. The coexistence of communities with systematic copying practices on the one hand, and *ad hoc* copying practices on the other, is mirrored by the later emergence of recognisable Christian scriptoria amidst a sea of Christian communities that were still content to make their own copies as the need arose.

How many Christian books were there at any one time?

It is possible to make some educated guesses concerning the

number of Christian books in use at a particular time. (Estimating the number of lost or destroyed books is another matter which I will not attempt here.) As a first observation, the number of Christian books in use should have increased with the Christian population. Secondly, not all books were equally in demand. The number of copies of a book required by a typical Christian community depended on how desirable the book was, and how many copies of the book were needed to service the entire community. Thirdly, the norm seems to have been for communal rather than individual ownership of Christian books. The number of books needed by the entire Christian population would therefore have been inversely related to the average number of Christians per Christian community. (The more Christians who could hear a single book read, the less books would be needed for all Christians to hear it read.) These observations form the basis of the following equation:

$$N = X \times B / C$$

N = no. of copies of a particular book

X = no. of Christians

B = average no. of copies of that book per Christian community

C = average no. of Christians per Christian community

I wish to emphasise that this equation is specific to a particular book such as Hebrews, and a particular time such as the year 250 CE. A separate equation is required for each book because the quantity B is not the same for all books. Also, the equation gives a point estimate (e.g., ten thousand copies in the year 250 CE) rather than a cumulative estimate (e.g., twenty thousand copies up to and including the year 250 CE).

The use of this equation can be illustrated by two examples: the first referring to the entire Greco-Roman world, and the second referring to a particular city.

Example 1: Copies of the four Gospels in 250 CE.

Rodney Stark (1997, 7) estimates that the rate of Christian

population growth must have been about forty percent per decade before the time of Constantine. He also finds that 'Christianity took root sooner where there were Jewish communities', and 'The more Roman and the less Eastern (Greek and Jewish) influence on a city's culture, the later its first church — Rome itself being the obvious exception' (139-140). He estimates that the total number of Christians in the Roman empire at 250 CE was about 1 200 000 (7).

Given that it was desirable (and, by then, technically feasible) to have a copy of the four Gospels in a single papyrus codex, I assume that every Christian church of average size would have had one copy of the Gospels. Being such a large book, it is probably unrealistic to expect a typical church to have had more than one.

The really difficult part of this example is the estimation of the number of Christians per Christian community. If accurate census returns were available for 250 CE, it would be a simple matter to divide the number of Christians by the number of meeting places to obtain the desired result. In the absence of such figures, it is necessary to tackle the problem by a more tortuous path.

Once again, Gamble's book proves useful. He gives a translation of the *Gesta apud Zenophilum* which details the official harassment of a Christian community in Cirta, North Africa, during the persecution under Diocletian (1995, 145-7). It can be ascertained from this account that there were seven readers who were forced to give up thirty-seven written works, one of which was a 'very large volume' that Gamble (147) thinks was probably a copy of the Gospels. Assuming a literacy rate of fifteen percent and that the only members of the church who could read were the readers, this implies that there were about 100 people in this Christian community. No doubt, literacy was not confined to the readers alone. If there were more than seven literate members and the literacy rate was fifteen percent, the estimate of 100 members is too low.

Another estimate of the average number of Christians in a Christian community can be obtained by the following approach. Stark (1997, 8) refers to the excavation of a house church at Dura Europus:

Excavations of a Christian building show that during the middle of the third century a house church was extensively remodeled into a building "entirely devoted to religious functions," after which "all domestic activities ceased".

(The quotes are from Michael L. White, *Building God's house in the Roman world*, Baltimore: John Hopkins University, 1990, 120. Gamble, 1995, 298, n. 11, also refers to the excavated *domus ecclesiae* at Dura Europus.) The need to remodel the house implies that the Christian community at Dura Europus had become too large to meet in the house on a casual basis by 250 CE. The house had six rooms which, I suppose, could have accommodated twenty people rather comfortably. Assuming that the community at Dura Europus was typical, this represents a lower estimate of the average number of Christians per community at the time.

Averaging the two estimates produces a figure of sixty Christians per Christian community. The equation then leads to the following result for the number of copies of the four Gospels in use around 250 CE for the entire Greco-Roman world:

$$N = X \times B / C = 1\,200\,000 \times 1 / 60 = 20\,000$$

The three variables on the right-hand of the equation are subject to large errors of, perhaps, one hundred percent each. Percentage errors must be added to obtain the overall error where multiplication and division are concerned. It follows that the total number of Gospels just estimated may well be too large or too small by a factor of three (i.e., 300%). Granted that the calculated figure is not too far off the mark, a survival rate of about one in ten thousand is implied if P45 and P4 + P64 + P67 represent the

only two surviving copies of the four Gospels from that era. (It is possible that P75 was also a four-gospel codex, in which case the survival rate would be about one in seven thousand.)

Example 2: Copies of Hebrews at Oxyrhynchus in 295 CE.

Table 1.2 of Stark's book (1997, 13) includes population estimates by Roger S. Bagnall. Stark (12) reports that 'Bagnall examined Egyptian papyri to identify the proportion of persons with identifiably Christian names in various years, and from these he reconstructed a curve of the Christianization of Egypt.' According to Stark's table, Bagnall estimates that 13.5% of the Egyptian population were Christian in 280 CE, and 18.0% were Christian in 313 CE. By interpolation, a figure of 15.5 % is obtained for 295 CE. As Oxyrhynchus is estimated to have had a total population of 30 000 (Epp, 1997, 27), this percentage implies that X is about 4700.

To estimate how many copies of Hebrews would have been in a typical church, I assume, once again, that each church would have a copy of the four Gospels. Given that the papyri listed in fig. 1 are from collections, there were about eleven copies of the Pauline letters for every eighteen copies of the four Gospels. It is not unreasonable to assume that Hebrews was habitually included in the Pauline letters, with the result that B is estimated to be about 11/18.

A report of night watchmen dated 295 CE lists a north and south church among other buildings in Oxyrhynchus (Epp, 1977, 27). If these were the only meeting points then the number of Christians per church would be about $4\,700 / 2$, which is approximately forty times as many as the estimate of sixty obtained before. Single congregations of 2 300 people seem implausible, so I will use a figure of 270 instead. This is the former figure of sixty multiplied by a factor of 4.5 to account for Christian population growth at Stark's rate of forty percent per decade over the period from 250 to 295 CE. The formula then gives:

$$N = 4\,700 \times (11/18) / 270 = 11 \text{ (approx.)}$$

Bearing in mind that the ratio of privately to communally owned books has already been estimated to be 3/40, the estimated number of privately owned copies is about $11 \times 3/40$, or just less than one.

We actually do have a copy of Hebrews from Oxyrhynchus that is dated to about this time. The papyrus designated P13 is written on the back of a roll, which could mean that it belonged to an individual rather than a church. If so, the implied survival rate is an incredible one hundred percent! This can hardly be regarded as an accurate estimate of the survival rate of ancient manuscripts, which has been calculated to be about $1 / 150\,000$ on the basis of census returns (Prof. Peter J. Parsons, Oxford summer school of papyrology, 1997). We are either incredibly fortunate to have had the sole private copy of Hebrews in Oxyrhynchus at 295 CE survive or, as is far more likely, something is amiss with my estimate. Part of the problem may be due to survival rates at Oxyrhynchus being higher than for other ancient cities. (I am not sure whether the rate of $1 / 150\,000$ refers to the entire empire or to Oxyrhynchus alone.) Also, the large uncertainties and numerous assumptions behind each variable mean that the final estimate of a survival rate has a large associated uncertainty.

All of these estimates are speculative. Perhaps the most problematic is the number of Christians per Christian community. Sociologists or historians may be able to cast light on what would have been an average-sized group. The capacity of a house is one limiting factor. Another important consideration is whether house churches tended to divide when they grew too large for a single house, or to move into purpose-built premises. Smaller communities would have had less resources than larger ones when it came to acquiring copies of Christian books. On the other hand, larger communities may have required more than one copy of each book to serve their needs. Finally, the demand for Greek manuscripts would have dropped as vernacular

translations became available.

Transport

The subject of manuscript transport was discussed previously while addressing the question of where Christian books were reproduced. Christian books spread through the Roman empire by means of Christians travelling between Christian communities:

Transmission took place by letter and messenger (letters requiring couriers) throughout the first five centuries of the church. It is no less typical of Augustine in the fifth century than it was of Cyprian in the third century, of Polycarp in the second, or of Paul in the first, to mention only a few examples. The travel of individual Christians or small delegations from one church to another, often over large distances, made the variety and breadth of Christian literature known to the congregations, thus increasing interest and demand, and also served as the efficient vehicle for the brisk movement of texts from one place to another (Gamble, 1995, 142).

Once books were locally available, there would be less need for copies to be brought in from elsewhere. In his 'dynamic view of textual transmission', Epp (1993b, 280-283) has made it clear that books were frequently transported from one part of the Greco-Roman world to another. This, however, should not be taken to mean that books were always imported from other parts of the world. As I said before, where there were local Christian networks through which books could be obtained, there would be little need for exotic copies. In general, copies of books were transported from where exemplars existed to where copies were needed. In my opinion, a Christian community would look no further afield than was necessary in order to obtain a copy.

Survival

A typical manuscript would serve its owners for some time before being retired. The life-spans of manuscripts affected how often they had to be replaced. There is little information available

from which to estimate how long a typical papyrus codex would have survived. In fact, Epp (1993b, 280) writes that 'the useful life of a papyrus MS in a liturgical setting is something I have not seen discussed.' In another study, Epp (1989, 262-4) points out that papyrus is a durable substance provided that it is kept away from hazards such as moisture, blowing sand, and white ants. He goes on to write (263), 'With all of these natural hazards — ancient and modern — it is remarkable that any considerable quantity of papyrus has survived.'

One of the greatest hazards to the survival of papyri has been human activity. Excavations in Egypt often destroyed papyri during the search for ancient artifacts. There are tragic stories of papyri being burned for their pleasant odour and of a ship laden with a season's finds catching fire and sinking (Epp, 1989, 264). Large quantities of papyrus-rich earth were carted away for use as a popular, though probably ineffective, fertiliser (Prof. Peter J. Parsons, Oxford summer school of papyrology, 1997). E. G. Turner estimated that thousands and perhaps millions of texts had been destroyed (Epp, 1989, 264).

These figures have some bearing on the subject under examination. By comparing the number of papyri that survive for a certain time with the number that originally existed, something analogous to a half-life for unstable isotopes can be calculated for papyrus codices. If each member of a population of objects has a half-life of $t_{1/2}$ then the number of objects left at time t is:

$$N(t) = N(0) \times \exp(-0.693 \times t / t_{1/2})$$

where $N(0)$ is the population at time zero.

A 'half-life' of approximately 135 years for papyrus codices is obtained using the previously obtained survival rate of one in ten thousand for manuscripts that have survived 1 800 years (i.e., from 200 CE until now). This survival rate is probably unrealistic since it was obtained by comparing the number of four-gospel codices that might have existed in the entire Roman empire with

those that survived in Egypt. Also, it does not take into account manuscripts that may have survived until now but have not yet been found. If a survival rate of one in one thousand is closer to the mark then the 'half-life' for papyrus codices is about 180 years. That is, the number of papyrus codices would halve every 180 years if no replacements were made. This does not seem to be a bad estimate. Papyrus is probably more durable than paper, and I would venture to say that at least one half of all books printed on acid-free paper would survive for 180 years if properly conserved. (A materials scientist would be able to throw more light on this subject.)

Codices were lost through misadventure as well as through normal wear and tear. Many Christian books were destroyed during the persecutions launched against Christians at various times. These were not uniform in their scope or execution, so that some Christian communities were far more likely to have their books confiscated and burned than others. I am not aware of any studies that attempt to estimate the proportion of Christian books destroyed during the Diocletian persecution. Gamble (1995, 132) writes,

The multiplication of copies of scripture [during the reign of Constantine] was more urgent because of the recent persecution of Diocletian, which had aimed at the systematic destruction of Christian books and sharply reduced their availability.

Such comments indicate that Diocletian's program of destruction was largely successful, perhaps consigning more than half of the Christians' books to the flames. A common theme in accounts of the Diocletian persecution is the reticence of some Christians to hand over their scriptures. In one account, the readers said their books were under the care of their bishop, Felix, who was on a journey to Carthage. Felix was later called before the magistrates, and his refusal to give up the books resulted in his execution. In another account, some Christian women did their best to hide their books, but were eventually found out (Gamble, 1995, 148). Some of the codices that we have today may have been hidden

away during these times of persecution.

Recovery

In order to be recovered, a manuscript has not only to survive but must have its hiding place discovered as well. As already discussed, the survival of manuscripts in a particular place depends on many factors, not the least of which are rainfall and human activity in the area. The probability of survival is markedly increased should the manuscript have enjoyed safe housing in libraries through the ages. This is, however, no guarantee of survival: manuscripts continue to be lost through libraries being ransacked, burned, bombed, or simply neglected.

If a manuscript survives the ravages of time, it still needs to be found and made available for study. There could be more New Testament papyri waiting to be recovered from dry places such as the deserts of Egypt and Israel. Some may have been carefully stored in jars or buried along with their owners. Systematic searches of places likely to preserve papyri have proven fruitful in the past, as in the expeditions of Grenfell and Hunt. Hopefully, searches of this kind will prove fruitful in the future. In Egypt, however, rising water levels caused by irrigation from the high Aswan dam may destroy any remaining papyri before papyrus-hunters can find them (Epp, 1989, 263).

Few, if any, New Testament papyri are likely to be hidden away in libraries, but there may be parchments. The libraries of Eastern Europe contain New Testament manuscripts and palimpsests that have not yet been edited and published. Discovery does not equate to full recovery in the sense of finds being made available to the scholarly community: the not so recent manuscript find at Saint Catherine's monastery in the Sinai is well known but the manuscripts have not yet been published in full.

The chance that a manuscript will be recovered is dependent on many different factors which vary with time and place. As a consequence, it would be difficult to construct a universally applicable model of manuscript recovery. As an alternative, a

specific model could be constructed for each manuscript or each place.

Computer simulation of textual development

Our earliest substantial remnants of New Testament manuscripts date to about 200 CE. Church Fathers provide us with indirect evidence of the state of the text at an even earlier stage. The same might be true for some versions as well. Often, however, indirect evidence is sparse, fragmentary, and subject to high levels of uncertainty. Consequently, it may not accurately represent the textual situation that actually prevailed.

The nature of early textual development can be investigated by an entirely different approach. Simulation has the potential to provide insights into early textual dynamics and to provide a basis for evaluating genealogical methods of recovering the original text. It makes use of reasonable assumptions to plot a probable course of development, and has the advantage of not being restricted by a lack of direct evidence, although it needs to be consistent with the boundary conditions that this evidence provides. For example, if the actual evidence shows that three major textual and spelling groups exist by, say, the fifth century then a valid simulation must produce tripartite grouping as well.

I will now describe some aspects of a computer-simulation of New Testament book production that I hope to implement one day. I believe that such a simulation would enable us to focus our attention on the consequences of particularly probable scenarios and to pay less heed to the consequences of any scenarios that are shown to occur infrequently. Weather forecasts provide an illustration of the logic behind this approach. We are accustomed to listening to weather reports and to planning accordingly. These reports are partly dependent on computer models that give a range of probable outcomes based on prevailing conditions. They do not provide certainty but do allow us to know what is likely to happen. Long-range forecasts are less reliable than short-range ones because the chaotic nature of the weather system gives rise

to more and more possible states in the long run. In the same way, the reliability of any prediction from a computer simulation of textual development depends on whether the underlying model is inherently chaotic and the extent to which the simulation must run free before meeting the boundary conditions imposed by extant evidence.

The proposed computer simulation has components relating to book production, transport, survival, recovery, copying, and correction. If each component is described by a probabilistic model then it can be simulated using established techniques which are based on computer-generated random numbers (more correctly, pseudo-random numbers). My intention is to give what I think are appropriate models of these components; their mathematical and statistical details will be touched upon only briefly.

Book production

From a numerical point of view, book production would have increased with the Christian population. Stark (1997, 7) employs an exponential model in which the Christian population is supposed to have grown at a rate of 40 percent per decade between 40 and 350 CE. Exponential growth can only be expected under certain optimal conditions. In most cases, the growth rate levels out at some point:

When considered over long periods of time, all populations of organisms, with one or two exceptions (for example, man), tend to show a zero rate of increase; in other words, the interaction of biotic potential [i.e., the maximum intrinsic rate of increase] and environmental resistance results in a more or less constant population size. Hence, the young growing population experiences detrimental effects of increased density, and growth is progressively inhibited until the population reaches some asymptotic level, or *carrying capacity*, which represents the maximum number of individuals that can be supported in a given habitat. The pattern of population growth which results is the S-shaped or sigmoid growth form, called the *logistic growth curve*,

in which growth starts slowly, accelerates rapidly in exponential form, and then decelerates and continues thereafter at a more or less constant level (Emmel, 1976, 102).

While it is somewhat inappropriate to refer to Christians as a population of organisms, parallels can be seen between this description of typical population dynamics and the historical growth of Christianity. At first, the population was quite insignificant by comparison with the total population of the Roman empire. As the population grew, it began to encounter 'environmental resistance' in the form of persecutions, among other things. In more recent times the growth rate has levelled off so that, on a global scale, Christianity has ceased to grow at the rate it once did.

A basic component of the simulation is a program clock that starts at the time of the first Christians and runs through until a specified ending date. At each 'tick' (i.e., time increment, such as a virtual year) of the clock, the simulation produces a number of virtual Christians that corresponds to the growth model that has been adopted. Exponential growth can be simulated by creating entities (in this case, Christians) at intervals determined by a random number generator conforming to the geometric probability distribution (see Hartley, 1988, 126). Logistic growth can be simulated by incorporating resistance to growth, an example of which is predation. (The total population of the empire is another limiting factor.)

If the resultant population expansion is divided among Christian communities then the program can be instructed to register that a book is required whenever a new community appears (i.e., a certain number of Christians appears in one place) or an existing community grows to the extent that it needs additional books. Books for individual ownership can be counted as part of these additional books. Should the size of the community decrease as a result of persecution, for example, the program does not register the need for a book until the community again grows to a size that is too great to be adequately served by the number of books

already possessed. Of course, these communities and books are virtual constructs: mere symbols that represent the realities.

Besides the production required to satisfy demand from an increasing Christian population, books are needed to replace those lost through wear and tear or misadventure. Whenever a book is lost from a community that is sufficiently big to require the book, a replacement is sought. In the simulation, there is no difference between a community that has need of a book because it has grown, and one that needs a book because it has lost an existing copy: in both cases the program registers that a copy is required and supplies it in due course.

Transport

Books were carried from place to place by people. As already stated, I believe that books would have been transported over long distances if necessary, but would have been obtained locally if possible. The transport of Christian books can be regarded as similar to a diffusion process, with an added process that allows a book to 'jump' a large distance. (The process that allows an entity to 'jump' from one place to another is named a Levy flight.) Methods of simulating such processes have already been worked out (Kaye, 1993). The spread of a bush fire can be modelled using a basic diffusion model supplemented with Levy flights to allow for the effects of airborne sparks. From a computing point of view, there is little difference between simulating the spread of Christian books and the spread of a bush fire.

An essential component of the transport model is a mathematical description of the distribution and movement of people in the Greco-Roman world. A suitable basis for this model is a square grid of horizontal and vertical lines that represent transport routes (i.e. roads and sea lanes). This grid can be superimposed on an actual map of the Mediterranean, and known cities placed at the appropriate intersections. The number of people travelling from one place to another is related to important factors such as distance and difficulty of travel between the places using an appropriate mathematical function.

In the simulation, virtual cities that already have Christian books serve as distribution points from which copies can diffuse and jump to other virtual cities. (A judicious identification of the city in which the book is thought to have been composed would have to be provided to initialise the program.) Depending on the magnitude of the simulation, the grid can be provided with more or less grid lines and more or less cities. Stark (1997, 131-2) provides a list of twenty-two important Greco-Roman cities along with their estimated sizes. These cities would serve as a suitable basis for this population model.

Given that book transport is more frequent between near neighbours, it is important to have a mathematical model of each city as well. The same kind of grid can be used, but this time the grid lines represent streets and canals. Individual Christian communities can be included in the model at this scale, with those nearest each other the most likely to exchange and compare books. Once this level is attained, the processes of copying and correction can be directly incorporated.

The following illustration shows how the simulation can work at this level. As a consequence of simulated population growth, the program selects a number of virtual communities as requiring a new copy of the virtual book at a particular 'tick' of the program clock. For each one of these recipient communities, the program then selects a source community to supply the exemplar. The source community must already be registered as having a copy of the book, and may be the recipient community, a nearby community, or a distant one. The computer chooses a source community according to the relative probability of each potential source community supplying the exemplar. For example, this source probability may vary as the inverse of the distance between source and recipient communities, raised to some power:

$$P(d) = k / d^n$$

where k is a normalisation constant, d is the distance between the communities, and n is a judiciously chosen positive number. (A strategy would have to be incorporated to handle the situation where the source community is the recipient community and the distance is therefore zero.) Once the source probabilities have been calculated, each potential source community is assigned a correspondingly large segment of the interval from zero to one. These segments are then arranged consecutively so as to cover the interval. The random number generator produces a number between zero and one, and the community whose segment is thereby chosen becomes the source community.

So far, I have assumed that a community would retain its exemplar, but this need not always be the case. Under certain circumstances, the community might give its own copy to another community. One circumstance that might cause an aged copy to be given to another community is the acquisition of a new copy. Such a scenario can be simulated by the program randomly selecting communities with books that are past a certain age. The selected communities are supplied with new copies by the program. The aged books are then assigned to other communities that have need of the book. Recipient communities can be selected using the same kind of procedure as just outlined for choosing source communities.

Survival

Simulation of exponential decay is also based on the geometric distribution. Each book that the simulation produces is subject to decay, and is destroyed (in a virtual sense) if the random number generator produces a number within the interval corresponding to its probability of destruction. In this way, approximately half of the books created at one 'tick' of the program clock will have disappeared after a number of 'ticks' corresponding to the specified 'half-life' of the writing medium.

Malicious destruction is fundamentally different from loss through wear and tear. In a realistic model, the probability function that describes the likelihood of books from a particular

location being confiscated would vary according to our historical knowledge of when and where book confiscation took place. Probability functions of this kind would have to be specified for every point of the population grid, but this would not be too difficult if only a few probability functions were developed and applied to entire regions of the grid.

Recovery

As far as the New Testament is concerned, experience tells us that the probability of recovering a papyrus is zero in all regions except Egypt. Non-biblical papyri have been recovered from places such as Herculaneum, so it is conceivable that New Testament papyri still lie undiscovered in places outside Egypt. Nevertheless, on present evidence the probability of survival outside Egypt is so low that it can be neglected. For manuscripts inside Egypt, the probability of recovery from a particular place is related to such factors as the area's annual rainfall, distance from irrigation, proximity to ancient Christian communities, whether papyri were purposely hidden or buried there, and whether it was ransacked during persecutions, conquests, or recent excavations. Models that take account of these features are adversely affected by gaps in our historical knowledge. Perhaps the best we can do is to create a probability function that is entirely empirical, reflecting the number of New Testament papyri that have actually been recovered in respective areas. The locality of Oxyrhynchus would therefore dominate as the place with the greatest probability of recovery.

This method of obtaining a probability function to describe recovery is also appropriate for parchment scraps that have been dug up in Egypt. However, a different approach is required for substantial parchment codices. Most of these have been recovered due to the historical circumstances of their preservation in various libraries and monasteries. A notable exception in the case of Hebrews is the Washington codex of Paul's letters, U16, that was recovered from the sands of Egypt.

A probability function that described the recovery of substantial

parchment codices would have to take account of whether a codex resided in a library whose contents would eventually be transferred to other libraries where the old codices would be safe. Not much is known of which libraries these might have been. There is circumstantial evidence suggesting that Sinaiticus found its way to Saint Catherine's monastery via the library at Caesarea, but no one knows the routes that manuscripts such as Alexandrinus, Vaticanus, and Claromontanus took to arrive where they are today.

One way of simulating the recovery of substantial parchment codices is to assign each simulated parchment codex a probability of eventually finding its way into a safe environment. An estimate of this probability would be equal to the number of library-preserved parchment codices that have survived from the time period that is simulated, divided by the cumulative number of parchment codices that the simulation produces over the same time period, allowing for exponential decay in their number. Another approach would be to have a few 'safe-houses' on the population grid. Any parchment codex which found its way to the location of a safe-house would then be certain to be recovered. By using the source probability function, certain safe-houses could be programmed to actively collect codices, thereby simulating the efforts of conscientious Christian librarians such as Pamphilus.

The recovery phase of the program is executed after the dissemination of books has been simulated. All those books which survive at the 'date' of recovery have a chance of being selected for recovery. A number of these survivors are selected according to the recovery model. This sample represents only a proportion of the virtual books produced during the simulation. In the same way, the sample of New Testament manuscripts preserved today in various libraries, learned institutions, private collections, and monasteries represents only a proportion of all the New Testament manuscripts ever produced. (I have not seen any discussion of the magnitude of this proportion. Jean Duplacy (1966, 127) estimated that between 1 500 and 2 000 Greek New

Testament manuscripts were copied in the fourth century. Given that these were all parchments and that nineteen parchments have been recovered (see appendix 1 of NA27), a recovery rate of about one percent is implied for fourth-century parchments.)

Copying

The production of each virtual book is associated with a copying event in which features are transferred from the source community's exemplar to the recipient community's copy. That is, the copying event simulates the activity of a scribe. As part of the initialisation of the program, the number of points where features can take on various states is specified. From now on, I will use the more familiar 'variation units' to refer to points, and 'readings' to refer to states. The virtual autograph and each copy consist of an array of variation units in which numbers represent readings. The autograph is assigned an initial value for each variation unit, and might appear as follows if ten units are specified:

0 0 0 0 0 0 0 0 0 0

Each variation unit has a number of possible readings. The probability that a scribe would select one of the readings might depend on which reading was in the exemplar, the readings of surrounding variation units, the scribe's proclivities, the environment, and so on. That is, each reading probability of each variation unit is conditional. In theory, a different model would be required for each reading of each variation unit for each scribe and each copying event. This is impractical, so an alternative strategy is necessary.

The simplest procedure is to have a single model of reading probabilities within a variation unit and to apply this model to all units. If binary results are desired then the model need only allow for two possible readings. (As it turns out, approximately one half of real textual variation units are binary.) A slightly more complicated but still practical approach would select a model for each variation unit from an array of predetermined models. These

might incorporate variations in the probabilities of the respective readings with time and place. In the case of binary variation units, if one reading had a consistently higher probability of being chosen than the other, this reading would eventually spread to a majority of copies.

I have proposed that exotic spellings were more volatile than exotic texts in the hands of a typical scribe. Such a disparity in the treatment of different kinds of variation could be simulated by using a different array of predetermined models for the simulation of the corresponding kinds of development. If my proposal were adopted for the underlying model then the array of models used for the spelling simulation would have a stronger tendency to favour local features than the array used for the textual simulation. Under these conditions, local spelling features would become dominant more quickly than local textual features over the course of a number of copying generations.

Not all scribes were the same, and some copied more creatively than others. This variation can be simulated by selecting a random number between zero and one that specifies the 'novelty' of a particular scribe's work and, as a consequence, a particular copying event. If the novelty is zero then the reading of every variation unit of the exemplar is transferred to the copy unaltered, while a novelty of one means that every variation unit is subject to change during the copying event. An intermediate value calls for the computer to select a corresponding number of variation units at random and to mark them as subject to change during the copying event. For example, if the novelty is 0.6 then six out of ten variation units are marked. (The novelties need not be uniformly distributed: a normal distribution or any other appropriate distribution may be used as the basis for their generation.)

Being subject to change does not imply that change will occur. Instead, it means that for every marked variation unit, a reading is selected according to the corresponding reading probability model. It is quite possible that the existing reading will again be

chosen. (This corresponds to the real situation where a scribe knew of alternative readings but nevertheless chose the reading of the exemplar.) Returning to the example of a virtual autograph given before, if the computer specifies a novelty of 0.6 and the reading probability model specifies simply that each variation unit has two readings of equal probability, independent of time and place, then the following might be the result of the first copying event:

0 0 0 0 0 1 1 0 0 0

Here, the computer marked six of the ten variation units as being subject to change. For each of these six, the reading was selected according to what amounts to the computer playing roulette with only two possible outcomes of equal probability. The equal probabilities of the two potential readings can be represented by two segments of length 0.5 placed consecutively to cover the interval from zero to one. A random number between zero and one is then generated. (The generator must now conform to the uniform distribution, so that all numbers in the interval are equally likely to be chosen.) If the number is greater than 0.5, the second reading is chosen; otherwise the first reading is transferred to the copy. In the example, the random nature of the event resulted in only two variation units being changed when six were subject to change. Whereas the most frequent number of changes is three out of six under these circumstances, two out of six changes can be expected to occur quite often.

In this way, variation is introduced into new copies. The place and date of each copy is determined by the population growth model. In order to convey more information, each copy could be assigned an identification number. The geographical coordinates, date, and exemplar of each copying event could then be attached to the string of numbers that represents the corresponding copy. Additional fields could be reserved for a destruction date and the identification numbers of any books against which the copy has been corrected.

The autograph is unique in requiring the user to specify a creation date and location. In order to make the simulation more realistic, this date should be some time after the date that Christian population growth is specified to have begun. Simulated population growth is then allowed to proceed for some time before the autograph is created. An existing Christian community in the place of composition is selected as the original location of the book, and the first copies disseminate from there. According to Alistair Stewart-Sykes (1996, 57), a copy of a business letter was usually kept by the sender in ancient times. If this applies to the New Testament letters then the autograph would be sent to the destination and a copy kept at the place of composition. In the simulation, source and recipient locations would then have to be specified for the autograph.

Correction

Correction is another process by which changes in the readings of a book's variation units can occur. A correction event can be simulated by obtaining an authoritative exemplar and applying its readings to the book being corrected, which I will call the working copy.

Behind every corrected working copy lies a decision to correct. Correction took place for a variety of reasons. In the context of a scriptorium, it was normal practice for a copy to be corrected against an authoritative manuscript. Where there were no scriptoria, some more conscientious individuals might have been in the habit of comparing manuscripts whenever the opportunity presented itself. Streeter (1925, 40) envisaged another occasion for correcting a manuscript: a bishop attending one of the synods might take along his copy of the scriptures and command one of his attendants to correct it against an authoritative standard located in the place he was visiting. In another scenario, an aged manuscript that was being transferred from one church to another might be corrected in order to bring it into line with the prevailing standard.

Certain manuscripts would have been regarded as more

authoritative than others, with authority being established according to important considerations such as a manuscript's apparent age and its conformity to the locally accepted text. In the simulation, an authority can be assigned to each book using a mathematical function that increases with a book's age and its conformity to nearby books. Authorities would then have to be assigned at each tick of the program clock.

When it comes to simulating correction, a working copy is selected according to a model that takes account of the reasons for correction mentioned before. Given a model that describes the probability of a manuscript being produced in a scriptorium, every book that the program deems to be created in a scriptorium is selected for correction. The program also selects a certain proportion of surviving books at random in order to simulate the correction of books outside scriptoria. Each book selected for correction at a particular tick of the program clock is then subjected to a correction event.

Once a working copy is selected for correction, an authoritative exemplar is required. Selection of the exemplar would have to take account of its distance from the working copy and its assigned authority; perhaps the most authoritative manuscript within a specified radius of the working copy could be selected. I have chosen not to consider the possibility of multiple exemplars here. There are reasons why simultaneous comparison with more than one exemplar would have been difficult and, therefore, exceptional (see Stewart-Sykes, 1996, 53-64).

Once the authoritative exemplar and working copy are selected, the correction event is executed. Some scribes were more thorough than others. Using an analogous strategy to the one employed for copying events, a proportion of the exemplar's variation units can be selected for transfer to the working copy. The program would assign a 'diligence' at each copying event, with a value of zero corresponding to none of the exemplar's readings being adopted, and a value of one corresponding to the working copy being made entirely conformant to the exemplar.

Correctors were capable of exercising independent judgement. A more adequate model of the correction process allows the corrector to select from the range of potential readings of a variation unit as well as to mechanically transfer readings from the exemplar. This is readily simulated by following each correction event by a copying event. Such a compound correction process may be illustrated with the following example:

A:	0	0	0	0	0	1	1	0	0	0
W1:	0	1	0	1	0	1	0	0	0	1
W2:	0	0	0	0	0	1	1	0	0	1
W3:	0	0	1	0	0	1	1	0	0	1

The first and second strings (A and W1) represent the authoritative exemplar and the working copy before correction, respectively. The next string (W2) represents the working copy after the correction event. In this case, not all of the readings of the working copy have been corrected to those of the exemplar because the diligence is less than one. (The virtual corrector has neglected to change a reading towards the end of the book — a common trait among real correctors.) The last string (W3) has a new reading that has been introduced by the corrector. This string, which corresponds to the end result of a compound correction event, could be produced by subjecting the string labelled W2 to a copying event with a novelty between zero and one.

As may be seen, 'mixture' is liable to occur if the diligence assigned by the program is less than one. Here, W2 is a mixture of W1 and A. What appears to be mixture, but is really due to creative scribal activity, occurs when a scribe produces a novel reading that happens to coincide with a reading of an independently copied manuscript (see Farthing, 1994, 215). In this example, if another copy could be found with the reading labelled 'one' in the third variation unit, it would appear that W3 was a mixture of this copy and a copy such as W2.

As a final point, former readings often remained legible in corrected manuscripts. Consequently, a scribe copying a corrected manuscript could choose between former and corrected readings as he or she worked. A more sophisticated rendition of the correction event could be developed to incorporate this possibility. A record of each variation unit's former readings would be required for the corresponding model to be implemented.

Some useful aspects of simulation

A simulation can be made more and more realistic by making its underlying models more and more accurate with respect to known historical circumstances. Many simulations can be run once the program has been completed. The effects of changing various parameters such as the frequencies of copying and correction can be investigated. Conversely, parameter values (such as the 'half-life' of papyrus codices) can be estimated by varying them until repeated simulations produce results consistent with real constraints (such as the actual number of papyrus codices).

Perhaps the most useful aspect is that the initial reading of the virtual text is known (cf. the virtual autograph shown before). Once the simulation has run its course, various strategies for identifying the original text, such as genealogical or majority text approaches, can be evaluated by comparing their results with the virtual autograph. Of particular interest is how the accuracy of these methods varies according to the proportion of books recovered and the extent of real and apparent mixture. Useful pieces of information that are not available for the real manuscript tradition include the complete genealogy of all books, the number of generations from each recovered book to the autograph, and the extent to which recovered books represent the autograph or the entire tradition.

Possible outcomes of simulation

While I have not written a simulation program that implements

these models of feature selection and manuscript dissemination, it is possible to draw some tentative conclusions concerning what the typical results of such a simulation might be.

Geographically specific texts

Should the novelty factor be quite high, the first copies of books to reach diverse places would be quite different from each other. According to the proposed model of source-book selection, local books are more likely to be selected for the purposes of copying and correction. As a consequence, local texts are likely to be preserved. Taken together, these suppositions result in diverse places having distinctive texts that continue to be distinct until universal standardising forces come into play. This is, in effect, Streeter's theory of local texts.

Drift and temporally specific texts

Forces of change, such as theological controversies and the combined effects of individual variations from many copying events, would drive local texts to wander over time. Any two initially similar systems that are separately subjected to randomly directed forces, such as might result from multiple copying events, can be expected to drift apart as time proceeds. The same goes for initially similar systems that are subjected to purposeful forces that operate on each system differently, such as might result from theological controversies in which different regions took different stances. Under the operation of such forces in a particular locality, texts that were contemporary would tend to be more similar than texts of different times. In addition, texts of different localities would tend to drift apart with time.

Extinction

Should the text in a particular locality have been partly or completely wiped out by some catastrophe, it would have been quickly replaced if the Christian population had survived relatively intact. This appears to be what happened at the beginning of the fourth century because the Diocletian persecution destroyed more books than Christian communities. The greater the degree of book destruction in a place, the more

replacement texts would have been imported from other localities once the persecution ceased. As a result, the local texts of places that suffered the worst loss of books would tend to be replaced by the local texts of places that escaped relatively unscathed.

This could account for the ascent of the Byzantine Imperial text that began in the fourth century. Perhaps a forerunner of what we now call the Byzantine text was the local text of Antioch just after 300 CE. If book destruction was particularly acute in Egypt but less severe in Syria, then Syrian replacements would tend to displace Egyptian texts. (The possibility of Palestinian replacements should also be considered in such a scenario.) Rather than being a recension that suddenly made all other texts obsolete, the Byzantine text may have been no more than a local text that was well placed to fill the gap left by the destruction of other local texts.

There is some evidence that Egypt did in fact suffer a massive loss of Christian books. The fifth century Washington codex of the Gospels (U32) exhibits block mixture, suggesting that a number of different exemplars were used in the composition of one of its ancestors or in its own composition. This codex was dug up in Egypt. A similar situation holds for Codex Alexandrinus (U2), which is also dated in the fifth century. According to my interpretation of the spelling maps, Alexandrinus was copied in Egypt. As is well known, its text is Byzantine in the Gospels. By contrast, my maps show that the text of Hebrews in Alexandrinus is closely related to the text copied by scribe A of Sinaiticus (U1). That is, both U2 and U32 represent Egyptian manuscripts copied not too long after the Diocletian persecution that show signs of having been composed from both local and imported texts. This is consistent with there being a shortage of purely Egyptian exemplars at the time.

Analogies with population biology

Analogous phenomena to the ones described here are well known in the field of population biology, where simulation is an established investigative technique. New Testament textual

researchers may stand to gain from results already obtained by biologists. For example, the principle of natural selection has an analogy in the New Testament manuscript tradition. Through a process that is better called scribal selection than natural selection, readings which were better adapted to their environment than their alternatives became dominant, as did texts with a majority of these readings, or so it seems. Such a process may help to account for the dominance of the Byzantine text-type, the development of which, according to Klaus Wachtel (1995, 199-201), occurred through a gradual process rather than through the production of major recensions. By using the same paradigm of selection, a study of readings whose relative frequencies increased over a particular time period may throw light on the prevailing conditions of that time (cf. Ehrman, 1995, 361-379).

Summary

The act of copying amounts to a scribe selecting a single feature from a set of potential features at each point of the document being copied. The selection process is affected by environmental conditions and individual proclivities that could, in theory, serve as the basis of a deterministic theory of scribal behaviour. This is unattainable in practice, but a probabilistic approach to the problem is feasible.

A probability can be associated with each potential feature. Scribal activity can then be regarded as the selection of features at each point of variation according to the associated probabilities. The relative frequency with which a feature occurs in extant manuscripts provides an estimate of its selection probability.

The fittest feature is the one that exhibits the greatest rate of increase in relative frequency over a given period. If it continues to be favoured, it will eventually become the most popular feature. In theory, the feature that is most likely to be original can be identified by backward extrapolation of trends in the relative

frequencies of alternative features. In practice, a lack of evidence makes this method subject to large uncertainties.

The dissemination of Greek New Testament manuscripts took place by a number of processes. Manuscripts were produced to satisfy demand which came mainly from the Christian community. Demand seems to have been limited by a low literacy rate rather than cost.

Since earliest times, the codex has been the normal format for Christian manuscripts. The early adoption of the codex form may have been due to its convenience for travellers. The contents of early Christian codices indicate which books early Christian communities found most desirable. By this standard, the Gospels were most popular, followed by the Pauline letters, Acts, the catholic epistles, and the Apocalypse.

A straight line is obtained when the sizes of certain New Testament books and collections are plotted against the dates that single-volume papyrus codices of these books and collections are estimated to have appeared. This line may represent the progressive maximum capacity of papyrus codices. If so, the capacity of papyrus codices was increasing in a linear fashion, possibly driven by the desire to incorporate more books into single volumes. Desired collections would then have been produced whenever the capacity of codices reached the required point.

If a Christian community wanted a book, it could arrange for a copy to be made where an exemplar existed; otherwise, it could borrow the exemplar while a copy was made. Books were conveyed from place to place by means of travelling Christians. Typically, the earliest copy of a book to reach a place would be from a distant locality. Under normal circumstances, copies would no longer be sought from distant places once the book was locally available.

Christian books were produced to supply a growing Christian

population and to replace books that had been lost. Like most other books of the time, they were privately copied. Christians took a particular interest in their literature, and copying enterprises existed from the beginning. There seems to have been a scriptorium at the Christian library in Caesarea by 300 CE, and there is circumstantial evidence that Christian scriptoria operated much earlier.

The number of Christian books that were in existence at any one time can be estimated using the following equation:

$$N = X \times B / C$$

N = no. of copies of a particular book

X = no. of Christians

B = average no. of copies of that book per Christian community

C = average no. of Christians per Christian community

Loss through dilapidation can be modelled by assigning a 'half-life' to manuscripts. Codices were also lost through intentional destruction and confiscation. Persecutions did not affect all places in the same way. The Diocletian persecution may have succeeded in destroying a significant proportion of Christian books in some places.

In some instances, the probability of recovery depends on factors such as local rainfall, and proximity to ancient Christian communities. In other cases, the major consideration is whether a manuscript was conserved in a library. A universal model of manuscript recovery is probably difficult to construct. As an alternative, manuscript-specific or locality-specific models might be considered.

Simulation provides an alternative approach to investigating early textual development. Probabilistic models are proposed for the simulation of particular aspects of textual development, including book production, transport, survival, recovery, copying, and correction. A corresponding simulation program

would work by generating random numbers that conform to these models.

The proposed simulation program is built around a program clock. Each 'tick' of this clock represents a conveniently chosen time interval (e.g., one year). With every tick of the clock, the simulation creates a number of new Christians in accordance with the adopted growth model. Resultant population expansion is divided into Christian communities that are assigned books according to a model that accounts for initial and ongoing demand.

Book transport can be regarded as similar to a diffusion process in which leaps are allowed. Such a model applies to the spread of bush fires as well as to Christian books. A square grid representing ancient transport routes provides a suitable context in which the transport model can operate. Virtual cities are placed at intersections corresponding to known population centres. Each city is provided with its own grid upon which individual Christian communities can be located.

The simulation creates and destroys virtual books according to the respective models of production and survival. A recovery phase occurs after the dissemination phase of the program. Only books that have survived until the specified recovery date have a chance of being recovered. Survivors are selected according to the recovery model.

Each virtual book consists of an array of a specified number of variation units. The potential readings of each variation unit are represented by numerals. Apart from the virtual autograph, all virtual books are produced by a copying event in which readings are transferred from a source community's exemplar to a recipient community's copy. The autograph is assigned an initial value for each variation unit.

In order to simulate copying, recipient and source communities are selected according to the respective models. One appropriate

model makes the probability of selecting a source community dependent on its distance from the recipient community. At each copying event, a certain proportion of variation units is marked as subject to change. This proportion reflects the creativity of the virtual copyist. Depending on the value of the copyist's 'novelty' factor, more or less variation units are marked as subject to change. For every variation unit so marked, the virtual copyist selects a reading according to a corresponding reading-selection model. In theory, a separate model would be required for every potential reading of every copying event. In a more practical approach, a limited number of distinct models are made available to the program for the purposes of simulating reading selection.

Correction is simulated by applying the readings of one virtual book (the authoritative exemplar) to another virtual book (the working copy). Authority is established by reference to a book's age and its conformity to the locally accepted text. Once the exemplar and working copy are selected, the correction event is executed by transferring a proportion of the exemplar's readings to the working copy. The proportion of transferred readings reflects the value of a 'diligence' factor selected for the virtual corrector. The introduction of novel readings by correctors can be simulated by compounding each correction event with a copying event.

Simulation has a number of potential advantages. It is a simple matter to run a simulation repeatedly once it has been set up. Unknown parameters can be estimated by running simulations with varying values until realistic simulation results are obtained. Also, certain strategies for identifying the original text on the basis of recovered texts can be evaluated because the initial state of the virtual text is known.

Concerning possible outcomes of a simulation constructed along these lines, the dissemination model should result in the production of local texts. Texts of different localities would tend to drift apart through the actions of both random and directed forces. In addition, contemporary texts would tend to be more

similar to each other than texts of different times. If, during a particular period, many of the books in one locality were destroyed while relatively few books were destroyed in a second locality, the text of the first locality would tend to be displaced by the text of the second locality. Analogous phenomena have been investigated in the field of population biology. For this reason, results already obtained in that field may be transferable to New Testament textual research.

Fig. 1: Coverage of NT books by early papyrus codices

Matt	P1	P37	P45	P53	P64/67	P70	P77		
Mark	P45								
Luke	P4	P7	P45	P69	P75				
John	P5	P28	P39	P45	P52	P66	P75	P80	P90
P95									
Acts	P29	P38	P45	P48	P53	P91			
Jas	P20	P23							
1 Pet	P72								
2 Pet	P72								
1 John	P9								
2 John									
3 John									
Jude	P72	P78							
Rom	P27	P40	P46						
1 Cor	P15	P46							
2 Cor	P46								
Gal	P46								
Eph	P46	P49	P92						
Phil	P16	P46							
Col	P46								
1 Thess	P30	P46	P65						
2 Thess	P30	P92							
1 Tim									
2 Tim									
Titus	P32								
Phlm	P87								
Heb	P46								
Rev	P47	P98							

Notes:

(1) This table is based on appendix 1 of NA27 (1993, 684-9). It covers NT papyri dated up to and including the turn of the fourth century (i.e., dated II to III/IV, inclusive).

(2) P12, P13, P18, and P22 are excluded as they are written on rolls.

(3) Papyri with **bold** sigla cover multiple books. Papyri whose sigla are not marked in bold may once have been part of multi-book collections.

(4) According to T. C. Skeat (1997, 1-34), P4 + P64 + P67 are part of the same manuscript that may once have contained all four Gospels. The sigla of P4 and P64/67 are accordingly marked in bold.

(5) P46 probably once contained 2 Thess and Phlm. J. Duff (1998, 587) suggests that it may even have included the Pastoral Epistles (i.e., 1 and 2 Tim and Titus).

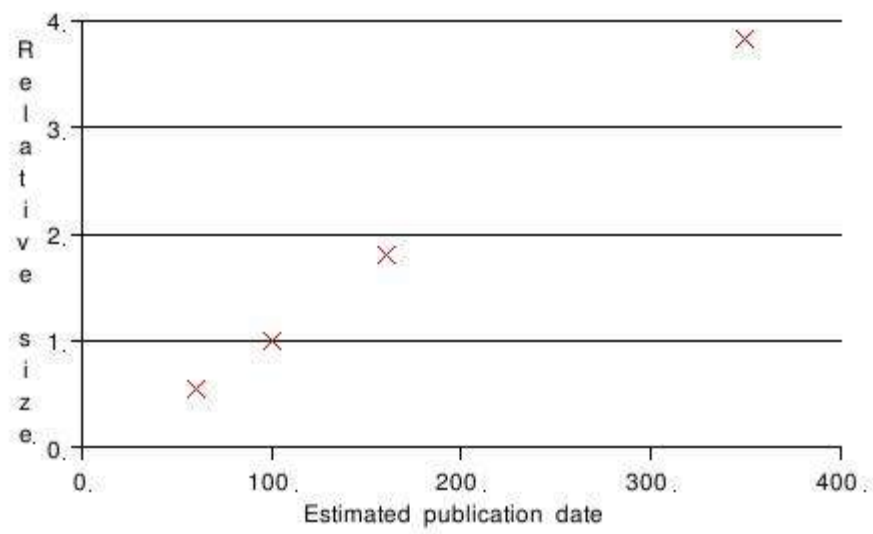
Fig. 2: Relative sizes of NT books and collections

	<i>Pages</i>	<i>Rel. size</i>
<i>Matt</i>	88	0.49
<i>Mark</i>	63	0.35
<i>Luke</i>	98	0.54
<i>John</i>	74	0.41
<i>Gospels</i>	323	1.79
<i>Acts</i>	90	0.50
<i>Catholic</i>	45	0.25
<i>Apostolos</i>	135	0.75
<i>Pauline</i>	180	1.00
<i>Revelation</i>	88	0.29
<i>All</i>	690	3.83

Notes:

- (1) The number of pages for each book is that of NA27.
- (2) Relative size is calculated by reference to the Pauline letters.
- (3) Apostolos = Acts + catholic letters.
- (4) Hebrews is included in the Pauline letters.

Fig. 3: Relative size vs. estimated publication date



References

- Aland, Barbara, Kurt Aland, Johannes Karavidopoulos, Carlo M. Martini, and Bruce M. Metzger (eds.). 1993. *Novum Testamentum Graece*. Nestle-Aland, 27th rev. ed. Stuttgart: Deutsche Bibelgesellschaft.
- Colwell, Ernest Cadman 1965. 'Scribal habits in early papyri: a study in the corruption of the text'. In *The Bible in modern scholarship: papers read at the 100th meeting of the Society of Biblical Literature*. Ed. J. Philip Hyatt. Nashville: Abingdon Press, 370-389.
- Dagpunar, John. 1988. *Principles of random variate generation*. Oxford: Clarendon Press.
- Duff, Jeremy. 1998. 'Π46 and the pastorals: a misleading consensus?' *New Testament studies* 44/4, 578-590.
- Duplacy, Jean. 1966. 'Histoire des manuscrits et histoire du texte du N.T.' *New Testament studies* 12/2, 124-139.
- Ehrman, Bart D. 1993. *The Orthodox corruption of scripture: the effect of early Christological controversies on the text of the New Testament*. New York: Oxford University Press.
- Ehrman, Bart D. 1995. 'The text as window: New Testament manuscripts and the social history of early Christianity'. In *The text of the New Testament in contemporary research: essays on the status quaestionis*. Festschrift in honour of Bruce M. Metzger. Studies and documents, 46. Ed. Bart D. Ehrman and Michael W. Holmes. Grand Rapids: Eerdmans, 361-379.
- Elliott, J. Keith. 1972. 'When Jesus was apart from God: an examination of Hebrews 2⁹'. *The expository times* 83/11, 339-341.

Emmel, Thomas C. 1976. *Population biology*. New York: Harper & Row.

Epp, Eldon Jay. 1989. 'The New Testament papyrus manuscripts in historical perspective'. In *To touch the text: biblical and related studies in honor of Joseph A. Fitzmyer, S.J.* Ed. Maurya P. Horgan and Paul J. Kobelski. New York: Crossroad.

Epp, Eldon Jay. 1993b. 'The significance of the papyri for determining the nature of the New Testament text in the second century: a dynamic view of textual transmission'. In *Studies in the theory and method of New Testament textual criticism*. Ed. Eldon Jay Epp and Gordon D. Fee. Studies and documents, 45. Grand Rapids: Eerdmans, 274-297.

Epp, Eldon Jay. 1997. 'The codex and literacy in early Christianity and at Oxyrhynchus: issues raised by Harry Y. Gamble's *Books and readers in the early Church*'. *Critical review of books in religion* 10, 15-37.

Farthing, Geoffrey P. 1994. 'Detailed textual stemmata by means of probability theory'. *AIBI 4 — Bible et informatique*, 214-222.

Gamble, Harry Y. 1995. *Books and readers in the early church: a history of early Christian texts*. New Haven: Yale University Press.

Garnet, Paul. 1985. 'Hebrews 2: 9: CARITI or CWRIS?'. *Studia Patristica* 18/1, 321-325.

Hartley, B. M. 1988. 'A computer method for simulating the decay of radon daughters'. *Radiation protection in Australia* 6/4, 126-130.

Head, Peter M. 1990. 'Observations on early papyri of the Synoptic Gospels, especially on the "scribal habits"'. *Biblica*

71/2, 240-247.

Head, Peter M. and M. Warren. 1997. 'Re-inking the pen: evidence from P. Oxy. 657 (P¹³) concerning unintentional scribal errors'. *New Testament studies* 43, 466-473.

Kaye, Brian Howard. 1993. *Chaos and complexity: discovering the surprising patterns of science and technology*. Weinham: VCH.

Kenyon, Frederic G. (ed.). 1933. *The Chester Beatty biblical papyri: descriptions and texts of twelve manuscripts on papyrus of the Greek Bible*. Fasciculus 1. *General introduction*. London: Emery Walker.

Matloff, Norman S. 1988. *Probability modeling and computer simulation: an integrated introduction with applications to engineering and computer science*. Boston: PWS-Kent.

Royse, James Ronald. 1981. 'Scribal habits in early Greek New Testament papyri'. Dissertation (ThD). Graduate Theological Union.

Skeat, T. C. 1969. 'Early Christian book production: papyri and manuscripts'. In *The Cambridge history of the Bible*. Vol. 2. *The West from the Fathers to the Reformation*. Ed. G. W. H. Lampe. Cambridge: Cambridge University Press.

Skeat, T. C. 1997. 'The oldest manuscript of the four Gospels?' *New Testament studies* 43/1, 1-34.

Stanton, Graham N. 1997. 'The fourfold Gospel'. *New Testament studies* 43/3, 317-346.

Stewart-Sykes, Alistair. 1996. 'Ancient editors and copyists and modern partition theories: the case of the Corinthian correspondence'. *Journal for the study of the New Testament* 61, 53-64.

Stark, Rodney. 1997. *The rise of Christianity: how the obscure, marginal Jesus movement became the dominant religious force in the western world in a few centuries*. San Francisco: Harper Collins.

Streeter, Burnett Hillman. 1925. *The four Gospels: a study of origins treating of the manuscript tradition, sources, authorship, & dates*. New York: Macmillan.

Wachtel, Klaus. 1995. *Der byzantinische Text der katholischen Briefe: eine untersuchung zur Entstehung der Koine des Neuen Testaments*. Arbeiten zur neutestamentlichen Textforschung. Band 24. Berlin: Walter de Gruyter.

Zipf, George Kingsley. 1949. *Human behavior and the principle of least effort: an introduction to human ecology*. Repr. 1972, New York: Hafner.

Zuntz, Günther. 1953. *The text of the epistles: a disquisition upon the corpus Paulinum*. Schweich Lectures of 1946. London: British Academy.

CONCLUSION

In the conclusion to his book *Human behavior and the principle of least effort*, George K. Zipf (1949, 543) wrote the following:

In ancient times one was wont to ask three penetrating questions:
What do you think? Why do you think so? What difference does it make? In closing let us ask what we have done; why we have done it; and what difference it all makes.

These are appropriate points to address in the conclusion to this thesis.

What is done

After the required manuscripts have been hunted down, the transcription method recommended for use with Dr Peter Robinson's *Collate* program is employed to transcribe the accessible papyrus and uncial Greek New Testament manuscripts of Hebrews. A set of computer programs is developed to process the transcriptions. After being checked for certain kinds of errors, the transcriptions are separated into the work of individual scribes. A synthetic text is constructed that contains the features of every manuscript in sequence. This synthetic text serves as the basis for a comprehensive collation that is not constrained by any one text. Data matrices are then extracted from the comprehensive transcription data. The specification of equivalents and the elimination of undesired features allows separate sets of data matrices to be produced for particular classes of variation. In this way, a data matrix can be generated for each scribe of each manuscript according to each kind of variation.

By applying multivariate analysis to the data matrices, maps of the respective kinds of variation are produced for the scribes and correctors who produced the manuscripts. These maps show that there are three groups of texts with shared affiliations. Three groups are also present in the spelling maps. This is a remarkable result because the spelling and textual maps are based on

separate sets of data.

Some manuscripts occupy different groups in the textual and spelling perspectives. I suggest that this phenomenon can be attributed to differential treatment whereby spelling variations were more volatile than textual variations in the hands of a typical scribe. If this is so, then the spelling maps provide a means of establishing manuscript provenances. This assertion rests on the hypothesis that the spelling groups correspond to geographical regions. A correlation test shows that there does appear to be a relationship between geographical location and map position for witnesses whose provenances are reasonably well known.

There is a correspondence between the maps and the known historical circumstances of the witnesses they portray. This engenders confidence that the maps convey historical information concerning witnesses whose histories are less well known. One of the three groups, which is identified with Egypt, contains witnesses dated from the third century up until the sixth century. The other two groups, tentatively identified with Palestine and Constantinople, are both represented by manuscripts whose dates range from the fifth century until the tenth century. This is consistent with Egypt ceasing to be a major Christian centre after the seventh century.

Multivariate techniques are not just useful for producing the maps that make up such a large part of this thesis. They also allow manuscripts to be classified. Classification schemes based on multivariate analysis are optimal. That is, they are as good as, or better than, any classification schemes currently used by New Testament textual researchers. Canonical variates analysis shows particular promise in this respect. For one thing, it confirms that the three groups exhibited in the maps are real.

An important aspect of modern science is an ability to deal with systematic and random errors. Probabilistic models play an important part in describing the behaviour of observational

errors. Palaeographers make do with sublinear dots and square brackets to indicate degrees of uncertainty. Moving forward from this point, I treat these respective levels of certainty as being characterised by different probabilities of being correct. This approach makes subsequent processing of transcriptions that contain uncertain data far less difficult.

A concern for quantifying errors carries on to the evaluation of the mapping technique. Due to sampling errors, every point plotted on a map represents only an approximation to the true position of a witness. As more information becomes available, the uncertainty in each position becomes less. Conversely, less information implies more uncertainty, so that the maps become completely unreliable if they are based on too little information. In order to allow the significance of a plotted position to be appreciated, methods are developed for constructing confidence intervals and probability ellipses. These indicate the probable extent of sampling errors.

After these rather rigorous pursuits, the study takes on a more speculative nature as textual development is discussed. Probabilistic models for the description of scribal behaviour and manuscript dissemination are proposed. Next, possibilities for the simulation of the earliest phase of textual development are discussed. Based on the proposed models, certain results of such a simulation can be envisaged without actually implementing a simulation program. Among possible outcomes are the development of local texts that gradually drift apart, and the extinction of certain local texts due to catastrophic destruction. At the end, I suggest that New Testament textual researchers may be able to learn some useful lessons from population biologists.

Why it is done

The principal reason for undertaking this study is a devotion to the text of the New Testament brought about by my Christian convictions. I count it a privilege to have been able to explore what I regard to be the most important body of writings in existence. This aside, there are more mundane reasons why the

study developed as it did.

I set out to expand upon the work of my honours thesis (Finney, 1991), in which P46, U1, and M2815 were manually aligned. Knowing something of computers and programming at the time, I thought that a much more reliable way of identifying places of variation would be to allow a computer to compare the texts. At first, my intention was to transcribe a broader set of manuscripts and to write a program to collate them. Through a happy set of circumstances, I found out about multivariate analysis. The application of multivariate analysis to comprehensive textual data has produced many unexpected results.

What difference it makes

The immediate implication of this work is that computer-assisted collation of New Testament manuscripts is possible. What is more, the multivariate analysis of collation results produces new insights into the textual development of the New Testament. Associated benefits include the identification of optimal classification schemes, and the possibility of establishing manuscript provenances by multivariate analysis of spelling variations.

One may ask what difference this will make to the actual text of the New Testament, as found in a critical edition of the future. To begin with, three distinct textual groupings have been identified among the ancient witnesses of Hebrews. One can be identified with Egypt and another with the Byzantine text. The third group does not necessarily equate to the Western text, but may be Palestinian. As a consequence of this finding, the possibility of local texts is back on the agenda. What is more, the relationship of this third group to the original text needs to be investigated. I do not think that it has any real claims to being the original text, but its relation to the better known textual groups requires investigation.

Some useful approaches to identifying what is most likely to be the original text have been suggested during the course of this

work. I will restate them here as parts of an integrated method. The most urgent need is for independent and reliable criteria by which to judge the authenticity of a reading. At the moment, many critical decisions rely on only a few principles, or on the opinions of a few learned people. It would be better to have a broad array of independent critical principles that were based on studies of actual scribal behaviour, such as those by Ernest C. Colwell (1965), James R. Royse (1981), and Peter M. Head (1990). It is no longer acceptable to base a judgement on what someone thinks a scribe might have done, when we have the means of discovering what a typical scribe is likely to have done.

Each principle established in this way could serve as an independent judge of the evidence. There is no reason why this panel could not include human experts, provided they made their decisions independently of the other judges. (This would restrict human judges to making decisions on purely stylistic grounds.) Some of the judges would be more reliable than others, and an important part of the method would be to estimate how reliable each judge is under the given circumstances, and to give weight to their judgements accordingly. These weighted judgements could be used as a basis of estimating the probabilities of respective features being the original feature.

The result would be a probabilistic description of which features were likely to be original. This is conceptually similar to the system used in the United Bible Societies editions, where the letters 'A', 'B', 'C', and 'D' are used to signify differing levels of certainty that the reading in the text is original. The proposed method would differ inasmuch as each reading would be assigned its own probability of being original to give the reader a more realistic impression of the relative merits of each reading.

Once the foundations for a method of this kind have been laid, the possibility of a critical edition of the New Testament that resides in a personal computer moves a step closer. All of the work of collation and grouping could be performed within the computer, along with critical decisions that do not require

thought (e.g., which reading occurs most often among the Egyptian group, or which reading is most frequent among witnesses that cladistic analysis identifies as the most primitive). These machine-based decisions could be supplemented by the prerecorded decisions of human experts at those places thought to be important enough to warrant the hard work of critical thought.

What remains to be done

This thesis represents an initial foray into a new world. Once machine-readable transcriptions of the manuscripts have been prepared, computer-assisted collation and analysis turns out to be reasonably straightforward. Entire vistas open up when established analytical techniques from other fields of study are applied to the Greek New Testament textual tradition. This bodes well for future inter-disciplinary efforts involving computer-assisted analysis and Greek New Testament texts.

It would be useful to extend the analytical techniques applied in this thesis to other parts of the New Testament. As far as the textual perspective is concerned, this could be achieved readily by employing the Institute for New Testament Textual Research's *Text und Textwert* series as a basis for sampling manuscript texts.

Far more work is required to apply the techniques to spelling variation. Full machine-readable transcriptions of scores of the most important manuscripts are required. Once the transcriptions are completed, a great deal of painstaking labour is required to separate textual and spelling variations. A sampling approach could be taken, whereby a few judiciously selected manuscripts were transcribed *in toto*. A set of words that are prone to spelling variation could then be isolated and used as the basis for sampling a larger number of manuscripts. (Maurice Robinson contributed to my thinking in this respect via discussions on the TC Internet discussion list.)

A recurrence of patterns already seen in Hebrews will confirm the validity of the approach. It would be particularly interesting

to see whether the spelling of Codex Alexandrinus remains within the same group throughout the New Testament. If it does, my proposal concerning the differential treatment of textual and spelling variation will remain viable. (Ulrich Schmid suggested that Codex Alexandrinus would make a suitable test candidate.)

Further work is required to determine whether it is better to use a binary or multistate approach to represent data. Also, the question of interpreting the map axes needs to be addressed in greater detail. I have worked on the implicit assumption that the axes correlate with geographical measures more than with temporal measures. Based on this assumption, the classical scaling maps are analogous to real maps, and concentrations of witnesses correspond to geographical locations. The axes may, however, have other correlations. Time seems to be ruled out as a major factor because two of the three groups cover roughly the same time period. If time was of principal importance, I would expect these two groups to merge. Nevertheless, time may still play an important part in giving the maps the shape they have. (These comments have been shaped by discussions with Bob Waltz.)

The end, at last

It has been said that a book is never finished, it is merely abandoned. Although much remains to be done, this thesis must be abandoned for all our sakes. I conclude with a scribal colophon quoted by Bruce M. Metzger (1981, 20): 'As travellers rejoice to see their home country, so also is the end of a book to those who toil'.

H CARIS META PANTWN UMWN

References

- Colwell, Ernest Cadman 1965. 'Scribal habits in early papyri: a study in the corruption of the text'. In *The Bible in modern scholarship: papers read at the 100th meeting of the Society of Biblical Literature*. Ed. J. Philip Hyatt. Nashville: Abingdon Press, 370-389.
- Finney, T. J. 1991. 'Establishing the text of PROS JEBRAIOUS: a collation of 3 manuscripts against the text of Nestle-Aland²⁶'. Dissertation (Honours). Murdoch University.
- Head, Peter M. 1990. 'Observations on early papyri of the Synoptic Gospels, especially on the "scribal habits"'. *Biblica* 71/2, 240-247.
- Metzger, Bruce M. 1981. *Manuscripts of the Greek Bible: an introduction to Greek palaeography*. New York: Oxford University Press.
- Royse, James Ronald. 1981. 'Scribal habits in early Greek New Testament papyri'. Dissertation (ThD). Graduate Theological Union.
- Zipf, George Kingsley. 1949. *Human behavior and the principle of least effort: an introduction to human ecology*. Repr. 1972, New York: Hafner.