

MICRO-STRUCTURAL CHARACTERISATION OF NON- EASEL PAINTED ARTWORKS

By

Lynn Chua

A thesis submitted for the
Degree of Master of Science (Research)

University of Technology, Sydney

August 2016

CERTIFICATE OF AUTHORSHIP AND ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all the information sources and literature used are indicated in the thesis.

Lynn Chua

22 Aug 2016

ACKNOWLEDGEMENT

I like to personally thank my academic supervisor, Associate Professor Barbara Stuart and co-supervisor, Dr. Paul Thomas, for their continuous encouragement and feedback throughout my research. Special thanks to Dr. Brian Reedy, Dr. Katie McBean, Dr. Linda Xiao and Dr. Verena Taudte for the instrumentation training and assistance in my technical questions at UTS. I also wish to express my gratitude to Mr. Jean-Pierre Guerbois (UTS) for his assistance in HF analysis, Dr. Elizabeth Carter (USyd) for her assistance in vivianite analysis and Dr. Ilaria Bonaduce (UniPisa) for assistance in my questions on the GC/MS analytical protocol for binder characterisation. In addition, Dr. Nick Proschogo (USyd) and Dr. Russel Pickford (BMSF, UNSW)'s provision of MS data processing softwares are much appreciated.

I wish to express my deepest gratitude to my internship supervisor, Dr. Gregory Dale Smith, senior conservation scientist at the IMA. The extensive learning experiences acquired at the IMA would not be possible without Greg's passionate and unequivocal guidance in conservation science research. Greg also contributed his feedback on the writing of the thesis. Special thanks to Dr. Victor Chen, dye analyst and full-time volunteer at the IMA (retiree chemist from Eli Lilly and Company). Victor taught me the spirit of perseverance in science and to think in the chemistry way, even if it is 'art' we are talking about. I also wish to thank John Goodpaster, IMA visiting professor from IUPU, who guided me with practical experience through several days of GC-MS troubleshooting.

Lastly it was an enjoyable experience working with the conservators through various projects. I like to thank Kerry Head (Objects Conservator at the AGNSW) and Natalie Wilson (Curator of Australian art at the AGNSW) for organising the sampling rounds and their enthusiasm in discussion of PNG highlands paint materials. I am also inspired and thankful to Claire Hoevel (Paper Conservator at the IMA), for her dedication and inquisitive mind in the conservation of artworks, which have kick-started most of the projects undertaken. I also like to acknowledge the contributions in data collection by Dr. Jay A. Siegel (IMA visiting professor from IUPU) and conservation documentation by Richard McCoy (Conservator of objects and variable art) for the "*Numbers 0-9*" project.

PUBLICATIONS AND CONFERENCE PRESENTATIONS

Accepted

Chua, L., Head, K., Thomas, P. & Stuart, B. 2016, 'Micro-characterisation of the colour palette of ceremonial objects from the Papua New Guinea Highlands: Transition from natural to synthetic pigments', *Microchemical Journal*, vol. 124, pp. 547-58.

Chua, L., Maynard-Casely, H.E., Thomas, P.S., Head, K. & Stuart, B.H. 2016, 'Characterisation of blue pigments from ceremonial objects of the Southern Highlands in Papua New Guinea using vibrational spectroscopy and X-ray diffraction', *Vibrational Spectroscopy*, vol. 85, pp. 43-7.

Chua, L. Hoeval, C., Smith, G.D. 2016, 'Characterization of Haku Maki Prints from the "Poem" Series using Light-Based Techniques', *Heritage Science*, vol. 4, no. 1.

Pending

Chua, L. Head, K. Thomas, P. & Stuart, B., 'Raman and FTIR Microscopy of organic binders and extraneous organic materials on painted ceremonial objects from the Highlands of Papua New Guinea', *Microchemical Journal*

Chua, L., McCoy R., Siegel, J., Smith, G.D. 'Polyurethane enamel paint characterization in Robert Indiana "Numbers 0-9" outdoor sculpture: Comparison of Paint failure before and after Conservation', *Studies in Conservation*

Conference Presentations

Chua, L., Head, K., Thomas, P. & Stuart, B. (2015, April). *Investigation of paints on ceremonial objects from the Highlands of Papua New Guinea*. Paper presented at the TECHNART Conference, Catania, Italy

TABLE OF CONTENTS

CERTIFICATE OF AUTHORSHIP AND ORIGINALITY	II
ACKNOWLEDGEMENTS	III
PUBLICATIONS AND CONFERENCE PRESENTATIONS	IV
TABLE OF CONTENTS	V
LIST OF TABLES	IX
LIST OF FIGURES	X
ABSTRACT	XVII
CHAPTER 1:INTRODUCTION.....	1
1.1 BACKGROUND	2
1.2 THESIS AIM	3
1.3 REFERENCES	5
CHAPTER 2:LITERATURE REVIEW.....	7
2.1 PAINT COMPOSITION.....	8
2.2 SAMPLING CONSIDERATIONS	9
2.3 INSTRUMENTAL TECHNIQUES	10
2.3.1 Vibrational Spectroscopy	11
2.3.1.1 FTIR spectroscopy.....	11
2.3.1.2 Raman Spectroscopy	13
2.3.1.3 Mapping/ Imaging	16
2.3.1.4 Data processing	16
2.3.2 Elemental Analysis	17
2.3.2.1 ed-XRF	17
2.3.2.2 SEM-EDS	18
2.3.3 GC/MS and Py-GC/MS	18
2.3.3.1 Sample Preparation Methods.....	19
2.3.3.2 Data Interpretation	21
2.4 CONCLUSIONS	24
2.5 REFERENCES.....	25
CHAPTER 3:CHARACTERISATION OF PAINT MATERIALS ON CEREMONIAL OBJECTS FROM THE HIGHLANDS OF PAPUA NEW GUINEA.....	47
3.1 BACKGROUND.....	48

3.2	MATERIALS AND METHODS	50
3.2.1	Techniques that eliminate interference for binder identification	50
3.2.1.1	Solvent extraction	51
3.2.1.2	HF pretreatment	52
3.2.2	FTIR microscopy	52
3.2.3	Raman microscopy	52
3.2.4	SEM-EDS	53
3.2.5	XRD	53
3.2.6	GC/MS	53
3.3	RESULTS AND DISCUSSION	54
3.3.1	White Clays	60
3.3.2	Black charred wood	62
3.3.3	Coloured pigments	64
3.3.3.1	Blue vivianite	65
3.3.3.2	Red and yellow ochres	70
3.3.3.3	Synthetic pigments	71
3.3.4	Binders	73
3.3.4.1	Plant-based organic matter	73
3.3.4.2	Lipid	77
3.3.4.3	Wax and wax ester	83
3.3.4.4	Natural resin	85
3.3.4.5	Synthetic resin	87
3.3.5	Metal Soaps	89
3.3.6	Extraneous organic materials	91
3.4	CONCLUSIONS	95
3.5	REFERENCES	97
CHAPTER 4:NON-INVASIVE ANALYSIS OF PIGMENTS AND LIGHTFASTNESS OF “POEM” SERIES PRINTS BY JAPANESE ARTIST HAKU MAKI		104
4.1	BACKGROUND	105
4.2	MATERIALS AND METHODS	106
4.2.1	Reference samples	106
4.2.2	Optical Microscopy	107
4.2.3	FTIR Microspectroscopy	107
4.2.4	Raman Microspectroscopy	107
4.2.5	Microfocus X-ray Spectroscopy (XRF)	107
4.2.6	Microfade Testing (MFT)	108

4.3	RESULTS AND DISCUSSION	108
4.3.1	White Haze.....	108
4.3.2	Pigments Identification	110
4.3.3	Microfade testing	118
4.4	CONCLUSIONS	122
4.5	REFERENCES.....	123
CHAPTER 5: INVESTIGATING CAUSES FOR POLYURETHANE PAINT FAILURE ON MODERN OUTDOOR SCULPTURES “NUMBERS 0-9” BY ARTIST ROBERT INDIANA		
126		
5.1	BACKGROUND.....	127
5.2	MATERIALS AND METHODS.....	131
5.2.1	Paint samples	131
5.2.2	UV-Vis microscopy and stereo-microscopy	132
5.2.3	SEM-EDS	132
5.2.4	Raman microscopy.....	133
5.2.5	FTIR microscopy	133
5.2.6	Py-GC/MS	134
5.2.7	Colorimetric measurements	134
5.3	RESULTS AND DISCUSSION	134
5.3.1	Layer stratigraphy	134
5.3.2	Foundation layers.....	139
5.3.2.1	Inorganic Extenders.....	140
5.3.2.2	Binder	141
5.3.3	Topcoat Binder.....	143
5.3.4	Topcoat Pigments.....	146
5.3.4.1	Characterisation of lead chromate family pigments in magenta, red, orange and yellow topcoats	146
5.3.5	Colour Measurements	150
5.4	CONCLUSIONS	152
5.5	SUPPLEMENTARY DATA	153
5.6	REFERENCES.....	154
CHAPTER 6: ANALYSIS OF “ESTES PARK, COLORADO” PREPARATORY SKETCH BY ARTIST GUSTAVE BAUMANN		
157		
6.1	INTRODUCTION.....	158
6.2	MATERIALS AND METHODS.....	159
6.2.1	FTIR Micro-spectroscopy	159

6.2.2	GC/MS	159
6.3	RESULTS AND DISCUSSION	160
6.3.1	FTIR micro-spectroscopy results	160
6.3.2	GC/MS results.....	162
6.3.3.1	Fatty acid fraction	162
6.3.3.2	Amino acid fraction	163
6.3.3.3	Monosaccharide fraction	164
6.4	CONCLUSIONS	165
6.5	REFERENCES.....	166
CHAPTER 7: CONCLUSIONS		169
7.1	CHOICE OF INSTRUMENTAL TECHNIQUES	171
7.2	DATA INTERPRETATION	172
7.3	OUTCOMES	173
7.4	FUTURE STUDIES.....	174
APPENDIX: VALIDATION OF ANALYTICAL PROCEDURE FOR MULTI-CLASS BINDER CHARACTERISATION IN THE SAME PAINT SAMPLE WITH GC/MS ..		176
A.1	INTRODUCTION.....	176
A.2	MATERIALS AND METHODS	179
A.2.1	Reagents	180
A.2.2	Method	180
A.2.3	Sample.....	181
A.3	RESULTS: METHOD VALIDATION	182
A.3.1	Phase 1- Validation with pure standards and raw materials.....	182
A.3.1.1	Monosaccharide fraction	183
A.3.1.2	Amino acid fraction	188
A.3.1.3	Fatty acid/ Terpenoid fraction	194
A.3.2	Phase 2- Validation with mock-up pigment/binder mixtures.....	196
A.3.2.1	Egg yolk.....	196
A.3.2.2	Egg yolk: Linseed oil (3p: 1p).....	198
A.3.2.3	Gum arabic: egg yolk (2p:1p).....	199
A.3.2.4	Gum arabic: gum tragacanth (1p:1p), zinc white, basium sulphate	200
A.3.2.5	Kaolin: mars yellow (1p:1p), deionised water	201
A.3.3	Phase 3- Validation with Baumann studio materials, comparing against Py-GC/MS and FTIR results.....	202
A.4	CONCLUSIONS	204
A.5	REFERENCES.....	205

LIST OF TABLES

Table 3-1: Photos of sampled areas of painted ceremonial objects collected from PNG Highlands	54
Table 3-2: Coloured pigments identified in the artefacts collected from the PNG Highlands	64
Table 3-3: List of natural vivianite sources in PNG Highlands	67
Table 4-1: Summary of the results from Raman and XRF analyses of pigments on selected Haku Maki prints from the “Poem” series	114
Table 5-1: Summary of pigment results identified in original and restoration paints	147
Table 7-1: Summary of case-study results	170
Table A-1: Binder class in raw materials	183
Table A-2: Percentage (%) monosaccharides composition in gum references	187
Table A-3: Percentage (%) amino acid composition of protein references.....	193
Table A-4: Percentage (%) aldose and uronic acid composition for single binders: gum arabic references and gum tragacanth reference, in comparison with mixed binders: gum arabic/ gum tragacanth and gum arabic/ egg yolk. Values in bold distinguishes a mixed binder from a single binder	201
Table A-5: Results of powder and varnish samples obtained from Baumann’s painting studio	203

LIST OF FIGURES

- Figure 3-1: Materials identified in PNG Highlands ceremonial objects 54
- Figure 3-2: FTIR spectra of white clay samples from (a) #258.1978 shield, (b) #245.1977 ceremonial hat, (c) #290.1979 tree fern head, where K = kaolinite, O = organic matter, Q = quartz, M = montmorillonite..... 61
- Figure 3-3: FTIR spectra of (a) fibre obtained from plant substrate on *Shield* (#490.1979) (b) black undercoat obtained from *Shield* (#265.1977), (c) black particles that filled the woven plant fibre on left arm of *Yupini* (#283.1978), (d) black particle obtained from grey paint on *Shield* (#260.1978) and (e) black particles from the black areas of *Sacred Stone* (#272.1978); L= lignin, C= cellulose, T= tannin, HT= hydrolysable tannin, CT= condensed tannin 63
- Figure 3-4: Raman spectra of blue vivianite sample taken from Timbuwara (#580.1979), (a) 785 nm, low power, no color change, (b) 785 nm, higher power, discoloration to yellow 66
- Figure 3-5: Raman spectra of blue vivianites at 514 nm in the spectral region 2700-3800 cm^{-1} (a) blue vivianite from Timbuwara (#18.2005) (b) blue vivianite from Mortar (#279.1977), the band at 3485 cm^{-1} suggests partial oxidation of Fe^{2+} to Fe^{3+} 67
- Figure 3-6: Distribution of blue pigments detected in the ceremonial objects, collected by Moriarty from various regions of the PNG Highlands between 1961 and 1972. Red dotted circle highlights the isolated occurrence of ceremonial objects containing vivianite..... 69
- Figure 3-7: Optical microscopic image of vivianite sample dispersed in glycerine at 200X magnification, collected from *Timbuwara* (#580.1979). Top left photo courtesy of AGNSW. 70
- Figure 3-8: (a) Distribution map of headquarters, sub-district posts and patrol posts recorded in PNG Highlands in 1966 (b) Distribution of red pigments identified on ceremonial objects obtained from different Highlands localities by Moriarty between 1961 and 1972..... 74

Figure 3-9: Exemplar FTIR spectra of red ochres containing (a) substantial organic matter (shield #302.1978) and (b) little organic matter (apron adorer #294.1977).....	75
Figure 3-10: FTIR spectra of various colored samples of residue (a) after water extraction and (b) after 10% HF pretreatment, S= plant sap or SOM. 77	77
Figure 3-11: Generic illustration of various binder classes of lipid, wax and wax esters containing long chain alkanes, esters and other functional groups.....	78
Figure 3-12: FTIR spectra of (a)(i) unaged pork lard reference (ii) red ochre paint on <i>Sacred Stone</i> (#272.1978), (iii) black particles from scrotum of <i>Yupini</i> (#283.1978), (iv) red SOP paint on <i>Judge's Wig</i> (#553.1979) and (v) Microcrystalline wax reference b) corresponding Raman spectrum of the samples in (a) collected at 785 nm	82
Figure 3-13: a) FTIR spectrum and b) Raman spectrum collected at 785 nm, of samples containing wax or wax esters.....	84
Figure 3-14: FTIR spectra of various resins identified	86
Figure 3-15: Total ion chromatogram of (a) #239.1977 varnish and (b) Tigaso oil reference.....	87
Figure 3-16: FTIR spectra of black particles obtained from black undercoat of <i>Shield</i> (#265.1977) (a) orange residue from CHCl ₃ /MeOH (2:1 v/v) extract (b) raw black particles, without solvent extraction, A = acrylate, T = tannin	89
Figure 3-17: EDS mapping of red synthetic paint containing zinc carboxylate soap from <i>Effigy</i> (#818.1979)	90
Figure 3-18: FTIR spectra of a) #533.1979 bark belt- white sample at the periphery of the red synthetic paint shows an abundance of zinc oleate (ZO) and zinc palmitate or zinc stearate (ZP/ ZS) b) #666.1979 mortar-grey sample shows an abundance of calcium palmitate (CP) and potassium stearate (PS).....	91

- Figure 3-19: SEM image at around 2000 X magnification c) FTIR spectrum and d) Raman spectrum collected at 785 nm, of the “white paint” on *shield* (#302.1978) in comparison with a bird excrement reference 92
- Figure 3-20: Photo of white efflorescence (indicated by black arrows) on *Shield* (#490.1979). FTIR spectrum of multiple spots on the white efflorescence sample shows a) C-chalk, b) possible gum-like binder or unresolved features of fungi, c) fungi features; d) SEM image of white efflorescence details fungal morphology residing at the surface of a substrate 94
- Figure 4-1: Prints by Haku Maki. (a) *Poem 71-29*, 1970, IMA#2013.419, 10.5”x7.25”, (b) *Poem 70-90*, 1970 IMA#2013.418, 6.5”x4.75”, (c) *Poem 70-70*, 1970, IMA#2013.417, 6.5”x4.5”, and (d) *Poem 71-61*, 1971, IMA#2013.420, 17.24”x10.5”. Gifts of Donald A. and Loryne M. Coffin. White efflorescence is visible in the black fields of (a). Photos courtesy of IMA..... 105
- Figure 4-2: Photomicrographs of the white efflorescence on *Poem 71-29*: (a) thin and soft web-like layer, (b) thicker clump of white filaments, and (c) transmission optical image of the fungal hyphae 109
- Figure 4-3: FTIR spectrum of (a) the white filaments shown in Fig. 4.2b and (b) a paper fiber taken from the print *Poem71-29*..... 110
- Figure 4-4: FTIR spectral comparison of (a) the black paint in *Poem 71-29* and (b) an aniline black reference pigment whose structure is shown in the inset ($n \approx 3$, $X^- = \text{HCrO}_4^-$, Cl^-) 111
- Figure 4-5: Raman spectrum collected at 532 nm, of the black background in (a) *Poem 70-70* compared to (b) a reference sample of aniline black watercolour. A similar match is obtained when (c) aniline black is diluted in a 4:1 ratio with lamp black in watercolour medium 113
- Figure 4-6: Raman spectra of (a) the orange paint in *Poem 71-29* at 785 nm, (b) chrome yellow (PY34) at 633 nm, (c) chrome orange (PO21) at 633 nm, (d) the red artist’s seal in *Poem 70-90* at 633 nm and (e) molybdate orange (PR104) at 633 nm..... 116

- Figure 4-7: Detail of the XRF elemental spectra of *Poem 71-29* (a) orange paint, (b) black paint, and (c) yellow paint.....118
- Figure 4-8: ΔE fading curves for the coloured areas of *Poem 71-29*. The colours being analysed are as indicated in the data traces, and the blue lines indicate average fading (with error bars) for the triplicate analyses of BWS 2 (upper) and BWS 3 (lower).....119
- Figure 4-9: ΔE fading curves for pure BASF aniline black (black squares) and in equal admixture with carbon black (black triangles) prepared as watercolour paints. These curves are compared to BWS 2 and 3120
- Figure 5-1: Image of “*Numbers 0-9*”, Robert Indiana, 1988.241-250, automotive paint on aluminum, Top: Before restoration in 2011, first displayed at IMA in 1992; Bottom: 4 years after restoration in 2011. Photos Courtesy of IMA.....127
- Figure 5-2: Close-up photos of some damages seen in “*Numbers 0-9*”, Robert Indiana, 1988.241-250, taken 4 years after restoration (a) paint delamination over a significant area revealing the aluminum surface in *Number 8* (b) paint delamination in *Number 2* reveals original paint that has not been properly removed. (c) paint loss along edge in *Number 7* reveals primer layer and signs of repainting.....130
- Figure 5-3: Example of the original paint system fabricated by Lippincott from *Number 2*. using terms based on original equipment manufacture (OEM).....136
- Figure 5-4: Front/back facings and side colours of *Number 7* original vs *Number 2* restored.....137
- Figure 5-5: Some examples of restored paint cross-sections demonstrating inconsistency in layer stratigraphy138
- Figure 5-6: Left: Front/ back paint cross-section of original *Number 5* with vis-microscopy. Right: SEM image shows that the first blue layer was formed by two coats, as seen by a distinct line in the middle139

- Figure 5-7: SEM image of *Number 0* paint cross-section taken from front/ back area, where aluminum (Al) and oxygen (O) represents aluminum oxides below the faring layer139
- Figure 5-8: White surfacer (layer 2) in cross-section of *Number 3* fluoresces yellow and is analogous to the distribution of Zn (zinc) in the EDS Hypermap image. Similar distribution of Zn is observed in white primer/surfacers in original *Numbers 0, 3, 4, 6, 7, 8 and 9* and Restored *Numbers 3, 5, 8 and 9*140
- Figure 5-9: Column 1- FTIR spectra of primer/surfacers in original (a-c) and restored (d-g) paints, where T - talc, K - kaolinite, M -magnesite, A - acrylate, NC - nitrocellulose, E -epoxy, U - urethane; Column 2- corresponding Py-GC/MS pyrolyzates; Column 3- the Numbers that contain the exemplar primer/surfacers142
- Figure 5-10: Images of cross-section in Original *Number 0* Grey reveal paint failure. Left: Optical microscopic image; Right: SEM image.....143
- Figure 5-11: Pyrogram of restored paint (*Number 6* red) vs original paint (*Number 2* green)144
- Figure 5-12: FTIR spectrum (a) at surface of topcoat original paint and (b) deeper within the topcoat original paint (c) restored paint after 3 years curing145
- Figure 5-13: Raman spectra (collected at 785 nm) and FTIR spectra of magenta, red, orange and yellow original topcoats. Selective spectral regions enable discrimination of molybdate orange (PR104) and chrome yellow (PY34), and allow relative pigment proportions in the paint mixture to be determined. 825, 340, 358 cm^{-1} are characteristic peaks for PR104, whereas 838 cm^{-1} and a fountain series of peaks centering at 340 cm^{-1} are characteristic of PY34.....151
- Figure 5-14: FTIR spectra of (a) Pigment reference PR122; (b) #48 red paint from uncured tin for *Number 6*, after extraction of binder with acetone; (c) the same paint as (b) without acetone extraction, where A : acrylate152

Figure 6-1:	Coloured pigments and varnishes in Baumann's studio.....	158
Figure 6-2:	Left: <i>Estes Park, Colorado</i> , 1926, Gustav Baumann, IMA# 2008.54, tempera over graphite on brown paper. Loose paint flakes available for analysis were purple, beige and white (Original location of paint is unknown). Purple sample: Sky area, Beige sample: Cloud area, White sample: White margin that borders the painting. Gift of Ann Baumann. Photo Courtesy of IMA. Right: A photomicrograph showing severe delamination of the paint.....	159
Figure 6-3:	FTIR spectrum of purple, beige and white samples indicate the presence of metal carboxylates.....	161
Figure 6-4:	Fatty acid profile of Blank (top) and Beige sample (Bottom), phthalic acid is attributed to contamination from vial cap	163
Figure 6-5:	Amino acid profile of blank (top), beige sample (middle) and egg yolk reference (bottom).....	164
Figure 6-6:	Monosaccharide profile of beige sample (top) and blank (bottom). Ions are extracted at $m/z = 249, 319, 408$	165
Figure A-1:	Summary of GC/MS combined analytical procedure	179
Figure A-2:	Schematic pathway of mercaptalation and derivatisation of carbohydrates.....	184
Figure A-3:	TIC of IS (mannitol), aldoses and uronic acids in a monosaccharide standard solution, whereby one peak represents one monosaccharide. Peak at $R_t = 27.85$ min also occurs in blanks.....	186
Figure A-4:	TIC of gum arabic (top), gum tragacanth (middle) and cherry gum (bottom).....	186
Figure A-5:	TIC of gum arabic (top trace) compared to the same sample with an extracted ion profile at 248, 304, 319 and 407 (bottom trace)	187
Figure A-6:	TIC of blank (top) and amino acid pure standard (bottom). Chemical structures of marker compounds indicate the extent of derivatisation	190

Figure A-7: Comparison of amino acid fractions: TIC of bone glue, hide glue and casein.....	192
Figure A-8: (a) TIC of HCl, (b) TIC of bone glue with conventional heating in 6M pure HCl, (c) TIC of an aliquot of the same bone glue hydrolysate in (b) after 5 cycles of rinsing with deionised water, EtOH and evaporation dry with N ₂ stream.....	194
Figure A-9: Fatty acid profile of pure standard	195
Figure A-10: TIC of linseed oil/ manila copal fatty acid/terpenoid fraction.....	196
Figure A-11: TIC of amino acid fractions from an unpigmented, unaged, dried egg yolk sample (top) 500 µg and (bottom) 460 µg, subjected to the same analytical procedure	198
Figure A-12: Fatty acid profile of (a) egg yolk:linseed oil (3p:1p), (b) egg yolk only and (c) linseed oil only. Samples are unpigmented and unaged. Retention times vary due to concentration difference	199
Figure A-13: Extracted ion profile (m/z= 249, 305, 319, 408) of gum fraction in gum arabic/egg yolk mix (top) and egg yolk reference (bottom).....	200
Figure A-14: Fatty acid profile of Baumann studio “printing varnishes”: A-S2-33 (top), D-S3-18 (middle) and H-S3-13 (bottom)	204

Abstract

Artist paint is one of the most heterogeneous materials encountered in museum conservation. While many scientific studies have been carried out on European easel paintings, less work has focused on other painted artworks, as well as works from other geographic regions. This thesis compiles results from four technical analysis projects on different types of non-easel painted artworks at the Indianapolis Museum of Art (IMA) and the Art Gallery of New South Wales (AGNSW), applying micro-analytical techniques, including FTIR microscopy, Raman microscopy, SEM-EDS, micro-XRF, XRD, Py-GC/MS, GC/MS and MFT. The painted artworks include 20th century ethnographic collections from the Highlands of Papua New Guinea, inked prints from the “Poem series” by Japanese artist Haku Maki, Robert Indiana’s painted aluminum outdoor sculptures, and Gustave Baumann’s home-made paint on paper. These works have not been previously investigated scientifically, and each presents specific museum curatorial and conservation concerns such as technical art history, lightfastness, paint degradation and treatment considerations. A range of natural and synthetic pigments, paint binders and deterioration products were characterized, contributing to the technical art history and understanding of paint degradation that informs conservation practices.