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**Τα Χειρόγραφα της Μονής Αγίας Αικατερίνης (Σινά) μέσα από τον
Φωτογραφικό Φακό: Από Γυάλινες Πλάκες στην Ψηφιακή
Φασματική Απεικόνιση**

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**The Manuscripts of Saint Catherine's Monastery (Sinai) through the
Photographic Lens: From Glass Plates to Digital Spectral Imaging**

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Abbreviations

ADC	Analog-to-Digital Converter
BC100	Book Cradle 100
CCD	Charge-Coupled Device
CMOS	Complementary Metal–Oxide–Semiconductor
CRI	Color Rendering Index
CSV	Comma-Separated Values
DC	Dublin Core
DOF	Depth of Field
DSLR	Digital Single-Lens Reflex camera
EMEL	Early Manuscripts Electronic Library
ES	Electronic Shutter
EXE	Executable (file name extension)
EXT4	Fourth Extended (file system)
FWF	Fonds zur Förderung der wissenschaftlichen Forschung (Austrian Science Fund)
HDD	Hard Disk Drive
ICC	International Color Consortium
IIF	International Image Interoperability Framework
IR	Infrared
ISO	International Organization of Standardization
IWS	Imaging Workflow Solution
LED	Light-Emitting Diode
LOC	Library of Congress (United States of America)

MD5	Message-Digest Algorithm Five
MSS	Manuscripts
NLG	National Library of Greece
NLI	National Library of Israel
PBC	Preservation Book Cradle
PCA	Principal Components Analysis
PPI	Pixels Per Inch
RGB	Red Green Blue
RH	Relative Humidity
SAM	Spectral Angle Mapping
SLDP	Sinai Library Digitization Project
SPP	Sinai Palimpsests Project
T	Temperature
TB	Terabyte
TIFF	Tagged Image File Format
TLG	Thesaurus Linguae Graecae
UCLA	University of California Los Angeles
UPS	Uninterruptable Power Supply
U.S.	United States of America
UV	Ultraviolet
VIS	Visible
XMP	Extensible Metadata Platform
ZFS	Zettabyte File System

Περίληψη

Τα χειρόγραφα της Μονής Αγίας Αικατερίνης (Σινά) μέσα από τον φωτογραφικό φακό: Από γυάλινες πλάκες στην ψηφιακή φασματική απεικόνιση.

Στα πρώτα στάδια ανάπτυξης αυτής της διατριβής, δεν γνώριζα την έκταση των πληροφοριών που θα ξετυλίγονταν στα προσεχή χρόνια της έρευνάς μου. Ξεκινώντας το ταξίδι μου σχεδίαζα στην καλύτερη καταγραφή ενός θέματος που με ενδιέφερε ιδιαίτερα, την ιστορία της φωτογραφίας χειρογράφων στη Βιβλιοθήκη της Ιεράς Μονής Σινά. Αντίθετα κατέληξα σε μια καλύτερη κατανόηση της ιστορίας της Ιεράς Μονής (I.M.) και στην τεκμηρίωση αυτής της ιστορίας. Σε απόσταση επτά ωρών οδικώς από το Κάιρο, βρέθηκα στο κέντρο της νότιας χερσονήσου του Σινά, περιτριγυρισμένος από βουνά 2000 μέτρων, Ιουστινιάνεια τείχη του 6^{ου} αιώνα που χτίστηκαν από γρανίτη, αρχαία χειρόγραφα, υπερσύγχρονο φωτογραφικό εξοπλισμό και γυάλινες πλάκες που απαθανάτισαν στιγμές από τις ζωές ανθρώπων του 20^{ου} αιώνα. Όσο παράξενη και αν είναι ως εμπειρία και όσο συναρπαστική και αν φαίνεται, συνοδεύεται από αρκετές προκλήσεις και δυσκολίες. Ορισμένες προφανείς δυσκολίες σχετίζονται με την τοποθεσία και το ξηρό κλίμα της ερήμου, άλλες είναι πιο εξεζητημένες και σχετίζονται με τα εύθραυστα αντικείμενα που επέζησαν σε αυτές τις συνθήκες.

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Η σπουδαιότητα του Σινά είναι γνωστή στον θρησκευτικό κόσμο του Δυτικού και Ανατολικού Χριστιανισμού, καθώς αποτελεί προορισμό προσκυνήματος ακόμη και πριν από τον 6^ο αιώνα από τη Βιβλική ιστορία με την οποία συνδέεται. Η άνθηση του μοναχικού ασκητικού βίου οδηγεί στην κατασκευή ενός βυζαντινού οχυρού (που αποτελεί την σύγχρονη I.M.) και της πρώτης Σιναϊτικής Βιβλιοθήκης. Στο πέρασμα του χρόνου και των αιώνων χειρόγραφα δωρίζονται, μεταφέρονται από προσκυνητές ή γράφονται επιτόπου προσθέτοντας στην ανάπτυξη της συλλογής. Με το τέλος των Ναπολεόντειων πολέμων γίνεται ασφαλέστερη και ποιο εφικτή η διάβαση προς την Ανατολή για τον ακαδημαϊκό κόσμο της Δύσης, έτσι η Μονή του Σινά γίνεται ένας

ελκυστικός προορισμός για εξερευνητές και μελετητές ειδικά μετά τις αρχές του 19^{ου} αιώνα. Εξερευνητές έχουν φτάσει στη Ι.Μ. και στο παρελθόν, αλλά πλέον εμφανίζεται ένα συστηματικό κύμα ερευνητών, με στόχο να μελετήσουν συγκεκριμένα τα χειρόγραφα και άλλους θησαυρούς τέχνης. Στις αρχές του 19^{ου} αιώνα η τεχνολογία κάνει άλματα προς τα εμπρός, καθιστώντας διαθέσιμες προς τους εξερευνητές φορητές συσκευές που μπορούν να αποτυπώσουν φωτογραφίες με σχετική ευκολία.

Το 1889 ο Rendel Harris ταξιδεύει με μια φωτογραφική μηχανή για να καταγράψει φωτογραφίες από τα χειρόγραφα του Σινά. Οι πρώτοι ερευνητές είχαν την δυνατότητα, είτε μόνο να καταγράψουν σε χειρόγραφες σημειώσεις τις μελέτες τους από τα χειρόγραφα, είτε στις πλέον θλιβερές των περιπτώσεων, να τα αποσπάσουν από την βιβλιοθήκη παίρνοντάς τα μαζί τους τα για να τα μελετήσουν μετά την επιστροφή τους από το Σινά. Η Agnes Smith Lewis και η Margaret Dunlop Gibson, εμπνευσμένες από τον Harris, κάνουν το πρώτο βήμα στη σύγχρονη έννοια της διατήρησης χειρογράφων μέσω της φωτογραφικής αποτύπωσης. Η Lewis και η Gibson ταξίδευσαν στο Σινά και αφιέρωσαν το μεγαλύτερο μέρος των πόρων τους για να φωτογραφίσουν ένα σημαντικό χειρόγραφο, τον Σιναϊτικό Συριακό κώδικα 30, αντί να το αφαιρέσουν από τη Βιβλιοθήκη. Με τη σειρά τους, έγιναν έμπνευση για πολλές άλλες αποστολές που ακολούθησαν. Η πιο γνωστή και αξιοσημείωτη αποστολή είναι αυτή του Wendell Phillips που οργάνωσε την αποστολή γνωστή ως το έργο φωτογραφικής αποτύπωσης με μικροφίλμ της Αμερικανικής Βιβλιοθήκης του Κογκρέσου το 1950. Με μεγάλες φιλοδοξίες να φωτογραφηθούν όλα τα χειρόγραφα της Βιβλιοθήκης, το έργο κατάφερε τελικά να φωτογραφίσει περίπου τα μισά από αυτά. Αλλά αυτό ήταν ήδη μια επιτυχία, καθώς άνοιξε τις πόρτες στους μελετητές για την επιστημονική έρευνα χειρογράφων από μια απομακρυσμένη Βιβλιοθήκη. Το μικροφίλμ μπορούσε πλέον να αντιγραφεί και να διανεμηθεί σε όλο τον κόσμο.

Λίγο μετά από μια άλλη αποστολή από τις ΗΠΑ πλησίασε το μοναστήρι το 1956. Αυτή τη φορά με ευρύτερα ερωτήματα, όχι μόνο για τα χειρόγραφα, αλλά και για την αρχιτεκτονική και την τέχνη των βυζαντινών εικόνων. Ο Kurt Weitzman και ο George Forsyth κατάφεραν να τραβήξουν όχι μόνο ασπρόμαυρες φωτογραφίες αλλά και έγχρωμες, καθώς η τεχνολογία είχε προχωρήσει για άλλη μια φορά, ζωντανεύοντας μέσα από έγχρωμες φωτογραφίες μινιατούρες χειρογράφων σελίδων. Μετά τον πόλεμο των Έξι Ημερών, μελετητές από το Ισραήλ έφτασαν στο πρόσφατα κατεχόμενο Σινά το 1969 με ενδιαφέρον να διατηρήσουν τα χειρόγραφα ολοκληρώνοντας το έργο που

η Βιβλιοθήκη του Κογκρέσου το 1950 δεν είχε τελειώσει. Αυτό το πολύ επιτυχημένο έργο της Βιβλιοθήκης των Ιεροσολύμων, ατυχώς δεν έγινε ευρέως γνωστό στην ακαδημαϊκή κοινότητα και μόλις πρόσφατα κέρδισε περισσότερη προσοχή μέσω της ψηφιοποίησης των μικροφίλμ που πραγματοποιήθηκε το 2016, καθώς και της επακόλουθης δημοσίευσης των εικόνων στο διαδίκτυο.

Το 1975 σηματοδοτεί μια σημαντική χρονιά στην ιστορία της Ιεράς Μονής με την ανακάλυψη περισσότερων από 1500 χειρογράφων (ελλιπή και πλήρη σώματα κωδίκων, σπαράγματα κτλ.), ξεχασμένων από καιρό σε μία κρύπτη του βόρειου τείχους. Οι επίσημες ανακοινώσεις της ανακάλυψης γίνονται το 1981, αλλά μετά από δύο δεκαετίες το 1998 δημοσιεύεται ανεπαρκής κατάλογος. Ο κατάλογος περιλαμβάνει περιγραφές των «Νέων Ευρημάτων» και μερικές μόνο φωτογραφίες χειρογράφων. Εμπνευσμένες από την ανακάλυψη, μια σειρά από αποστολές λαμβάνουν χώρα στη Σιναϊτική Βιβλιοθήκη για να διευκολύνουν συγκεκριμένες γλωσσικές ομάδες της νέας συλλογής. Γεωργιανά, και σλαβικά χειρόγραφα προσελκύουν ένα ιδιαίτερο ενδιαφέρον και σημαντικές ανακαλύψεις αναδύονται, ιδίως μιας από καιρό ξεχασμένης γλώσσας από ένα Χριστιανικό βασίλειο του Καυκάσου (Καυκάσια Αλβανικά). Με την ανάπτυξη της ψηφιακής φωτογραφίας καταφθάνει νέος εξοπλισμός στη συλλογή για την υποστήριξη των προσπαθειών συντήρησης και μελέτης. Η Ιερά Μονή Σινά επιχειρεί για δύο δεκαετίες (1997-2017) να ψηφιοποιήσει μόνη της την τεράστια συλλογή χειρογράφων. Ο βιβλιοθηκάριος Πατέρας Ιουστίνος συνειδητοποιεί τη σημασία μιας συστηματικής προσέγγισης για ένα μεγάλης κλίμακας έργο με περισσότερους συνεργάτες και φωτογράφους. Εν τω μεταξύ, επισταται και πάλι η προσοχή στα σβησμένα κείμενα της Σιναϊτικής Βιβλιοθήκης. Το 2011 το Πρόγραμμα των Σιναϊτικών Παλιμψήστων ξεκινά τις προσπάθειές του να απεικονίσει με την βοήθεια πολύ-φασματικής φωτογράφισης 7400 σελίδες παλιμψηστων μέχρι το 2017. Με τη συμμετοχή μου ως επικεφαλής φωτογράφος σε αυτό το έργο, ανέπτυξα το ενδιαφέρον μου για την ιστορία της φωτογραφίας και καθιερωθήκαν τα θεμέλια για τη διατριβή μου. Το 2018 ξεκίνησε η συστηματική ψηφιοποίηση όλων των χειρογράφων της Σιναϊτικής Βιβλιοθήκης μέσω του Προγράμματος Ψηφιοποίησης, μια προσπάθεια για την διαδικτυακή δημοσίευση 4500 χειρογράφων με την υποστήριξη του Early Manuscripts Electronic Library (EMEL) και του Πανεπιστημίου της Καλιφόρνια στο Λος Άντζελες (UCLA).

Έχοντας συγκεντρώσει για πρώτη φορά μαζί όλες τις πληροφορίες για τις φωτογραφικές αποστολές αφιερωμένες στη διατήρηση και μελέτη χειρογράφων στη Βιβλιοθήκη του Σινά, μπόρεσα να διακρίνω ενδιαφέροντα μοτίβα και να κάνω συγκρίσεις. Από τις 19 γνωστές φωτογραφικές αποστολές και έργα, που πραγματοποιήθηκαν από τον 19ο έως τον 21ο αιώνα, μόνο τρεις από αυτές ήταν «ελληνικές» πρωτοβουλίες (16%). Αυτό δείχνει την προσβασιμότητα (ως ένα βαθμό, και με εξαιρέσεις σε αυτό το συμπέρασμα) της Ελληνικής Ορθόδοξης Ιεράς Μονής της Αγίας Αικατερίνης σε «ξένους» μελετητές, προκειμένου οι τελευταίοι να μελετήσουν και να προωθήσουν την κληρονομιά που οι μοναχοί διαφύλαξαν στην Σιναϊτική έρημο επί αιώνες. Ακόμη και όταν η Ιερά Μονή έκρινε ότι οι συμφωνίες δεν τηρήθηκαν όπως είχε αρχικά προγραμματιστεί (κεφάλαιο 1.3.7, Βιβλιοθήκη του Κογκρέσου), συνέχισε να δέχεται άλλες ομάδες για την έρευνα των χειρογράφων, αλλά διατήρησε την ανάμνηση της παρατυπίας ως μάθημα προς την καλύτερευση των νέων συνεργασιών (κεφάλαιο 1.3.9, Εθνική Βιβλιοθήκη του Ισραήλ). Τελικώς, περισσότερη διαφάνεια σήμαινε περισσότερη υποστήριξη για τη Ιερά Μονή του Σινά.

Συγκρίνοντας αυτές τις 19 γνωστές αποστολές, είναι φανερό ότι η κοινή και κύρια δυσκολία είναι η απομακρυσμένη τοποθεσία της Σιναϊτικής Βιβλιοθήκης. Ο φωτογραφικός εξοπλισμός και ο τύπος των φιλμ των πρώτων ερευνητών και μελετητών καταγράφεται για κάθε αποστολή, καθώς είναι σημαντικός παράγοντας για την καλύτερη κατανόηση της ανθεκτικότητας και αναγνωσιμότητας των παραγόμενων αποτελεσμάτων. Από τον 19ο αιώνα οι μελετητές έπρεπε να μεταφέρουν εύθραυστες γυάλινες πλάκες σε καμήλες. Τον 20ο αιώνα η ηλεκτρική ενέργεια παρήχθη από φορητές γεννήτριες ντίζελ και ήταν τόσο ασταθής που προκάλεσε διαφορές στην έκθεση των φωτογραφιών (άλλες εμφανίζονταν σκοτεινότερες και άλλες φωτεινότερες). Ακόμα και στον 21ο αιώνα οι διακυμάνσεις της ηλεκτρικής ενέργειας μπορούν να προκαλέσουν ζημιές σε ηλεκτρονικές ευαίσθητες συσκευές εάν δεν ληφθούν μέτρα προστασίας. Η επισκευή ελαττωματικού εξοπλισμού, ήταν και παραμένει δύσκολη στην έρημο του Σινά, για αυτό τον λόγο οι διοργανωτές ενός έργου πρέπει ακόμα και σήμερα να προ-σχεδιάσουν για το απροσδόκητο όπως και προσπάθησαν να κάνουν τα τελευταία 100 χρόνια.

Το δεύτερο μέρος της διατριβής μου είναι αφιερωμένο στην έρευνά μου σχετικά με τις σύγχρονες προσπάθειες ψηφιοποίησης στις οποίες συμμετείχα. Ξεκινώντας με την εξήγηση για το τι είναι τα παλίμψηστα και γιατί είναι σημαντική η μελέτη των

διαγραμμένων στρωμάτων χειρογράφων, παραθέτω τις προηγούμενες προσεγγίσεις σε αυτή την κατηγορία χειρογράφων και τα διδάγματα που αντλήθηκαν από προηγούμενες αποστολές. Σήμερα η τεχνολογία έχει εξελιχθεί, υιοθετώντας μια μη-επεμβατική προσέγγιση στην μελέτη ιστορικών κειμηλίων. Το κύριο επίκεντρο των φωτογραφικών αποστολών έχει μετατοπιστεί στη συνεργασία ενός ευρέος φάσματος επιστημών. Τεχνικοί υπολογιστών, επιστήμονες οπτικών μέσων και απεικόνισης, συνεργάζονται με διαχειριστές δεδομένων, μελετητές και φωτογράφους. Με στόχο την παραγωγή αντικειμενικών αποτελεσμάτων που μπορούν να μελετηθούν από ένα ευρύ φάσμα ερευνητών και όχι μόνο ένα ζεύγος ματιών. Αυτή η εξέλιξη όμως, δεν θα ήταν δυνατή χωρίς το πρωτοποριακό έργο των ερευνητών του παρελθόντος, οι οποίοι παρόλο που προκάλεσαν φθορές στα χειρόγραφα, προσέλκυσαν το ενδιαφέρον πολλών άλλων ερευνητών στη Σιναϊτική συλλογή.

Η πρώτη προσπάθεια καταγραφής των παλιμψήστων περιελάμβανε χημικές ουσίες και την έκθεση τους σε έντονες πηγές φωτός ενέργειας (ήλιος), τώρα όμως μέσω του Sinai Palimpsests Project η έκθεση ενέργειας προς το αντικείμενο ρυθμίζεται πλέον με φωτεινές πηγές LED (οι οποίες δεν παράγουν θερμότητα στην επιφάνεια του αντικειμένου). Σημαντική έμφαση δόθηκε στους αλγορίθμους επεξεργασίας ηλεκτρονικών υπολογιστών και στον αντικειμενικό προσδιορισμό των κειμένων, καθώς και στη συλλογή πληροφοριών με τη μορφή μεταδεδομένων για την υποστήριξη της ηλεκτρονικής δημοσίευσης των χειρογράφων. Το αποτέλεσμα αυτού του έργου ήταν η (μέχρι τώρα) ανακάλυψη 307 σβησμένων κειμένων που συμβάλουν στην ακαδημαϊκή γνώση. Μια συνεισφορά όχι μόνο προς την φιλολογία αλλά και προς την τεχνολογική πρόοδο της φασματικής απεικόνισης. Το Sinai Palimpsests Project βασίζεται στις επιτυχημένες τεχνικές προηγούμενων έργων όπως το πρόγραμμα "Archimedes Palimpsest", προσθέτοντας επιπλέον, τόσο νέο εξοπλισμό όπως τις υποκείμενες φασματικές πηγές φωτισμού, όσο και προηγμένες τεχνικές επεξεργασίας εικόνας. Αυτές οι καινοτομίες χρησιμοποιούνται πλέον και από άλλα έργα φασματικής απεικόνισης ανά τον κόσμο. Η προσωπική μου ανακάλυψη μέσα από τον σκοτεινό φωτογραφικό θάλαμο ήταν μια φαρμακευτική συνταγή του 6^{ου} αιώνα για τη προετοιμασία και την εφαρμογή του «Φιλετέριου» σε δαγκώματα σκορπιού.

Η επιτυχής πορεία του Sinai Palimpsests Project ενθάρρυνε τη Ιερά Μονή του Σινά να προσκαλέσει τους συνεργάτες της (EMEL και UCLA) στην πλήρη ψηφιοποίηση της συλλογής χειρογράφων. Μέσα από το ρόλο μου ως διευθυντής απεικόνισης συνάντησα

παρόμοιες προκλήσεις με αυτές των προηγούμενων εξερευνητών και μελετητών. Ο βαρύς και εύθραυστος φωτογραφικός εξοπλισμός έπρεπε να μεταφερθεί και να εγκατασταθεί στην έρημο του Σινά. Ο χώρος είναι ένα ιδιαίτερο ζήτημα μέσα σε ένα οχυρό του 6^{ου} αιώνα, και νέες υποδομές για το ηλεκτρικό δίκτυο και το δίκτυο υπολογιστών έπρεπε να τοποθετηθούν σε ένα ανακαινισμένο δωμάτιο που βρίσκεται κάτω από τη Βιβλιοθήκη στη νοτιοανατολική πτέρυγα της Ιεράς Μονής. Το αποτέλεσμα είναι ένα υπερσύγχρονο φωτογραφικό εργαστήριο με τέσσερις σταθμούς ψηφιοποίησης και διακομιστές αποθήκευσης για τη συλλογή των Σιναϊτικών χειρογράφων. Έχοντας ως προτεραιότητα την ευθραυστότητα και τη ανεκτίμητη αξία των αντικειμένων, σχεδίασα μια αποτελεσματική και ασφαλή ροή εργασίας για τη διαδικασία ψηφιοποίησης.

Εξεζητημένες προκλήσεις σχετικά με την ονομασία των ψηφιακών φωτογραφιών και την καταγραφή πληροφοριών επιλύθηκαν με την εμπειρία που συσσωρεύτηκε από το Sinai Palimpsests Project και την ανταλλαγή πληροφοριών μεταξύ άλλων ιδρυμάτων ψηφιοποίησης όπως η Αποστολική Βιβλιοθήκη του Βατικανού και η Πανεπιστημιακή Βιβλιοθήκη του Cambridge. Το αποτέλεσμα αυτού του έργου είναι η ηλεκτρονική δημοσίευση 400.000 φωτογραφιών στο διαδίκτυο (Ιούλιος 2021) που περιλαμβάνουν χειρόγραφα από την Παλαιά συλλογή (χειρόγραφα γνωστά έως το 1975) και την συλλογή Νέων Ευρημάτων (χειρόγραφα που ανακαλύφθηκαν το 1975), με σχέδια να περιλαμβάνουν την δημοσίευση έως και 1.500.000 σελίδων μετά την ολοκλήρωση της ψηφιοποίησης της Σιναϊτικής Βιβλιοθήκης. Είναι η πρώτη φορά που η συλλογή των Νέο Ευρεθέντων χειρογράφων παρουσιάζεται συστηματικά στο ευρύ κοινό και διατίθεται σε όλους τους ερευνητές.

Το τελευταίο κεφάλαιο της διατριβής εμβαθύνει σε μια ξεχασμένη φωτογραφική συλλογή γυάλινων πλακών από τις αρχές του 20^{ου} αιώνα. Κατά τη διάρκεια των επισκέψεών μου στο Σινά, ανέπτυξα ιδιαίτερο ενδιαφέρον για έξι παραμελημένα κουτιά από χαρτόνι που περιείχαν εύθραυστες γυάλινες πλάκες. Με την υποστήριξη του Βιβλιοθηκάρου Πατέρα Ιουστίνου Σιναΐτη, κατέγραψα, ψηφιοποίησα και δημιούργησα μια λύση για την μακροπρόθεσμη αποθήκευση των γυάλινων πλακών.

Η προκύπτουσα ψηφιακή βάση δεδομένων των γυάλινων πλακών αριθμεί 1264 αντικείμενα. Κάθε αντικείμενο περιγράφεται από τις φυσικές του ιδιότητες (διαστάσεις και αξιολόγηση διατήρησης) καθώς και από το περιεχόμενο των φωτογραφιών που

ομαδοποιήθηκε ανά είδος. Οι γυάλινες πλάκες συμβάλλουν στην καλύτερη κατανόηση της ιστορίας της Ιεράς Μονής της Αγίας Αικατερίνης στις αρχές του 20^{ου} αιώνα, καθώς απεικονίζουν κτίρια, αντικείμενα, ανθρώπους και δραστηριότητες του παρελθόντος. Από τη εργασία μου με αυτή φωτογραφική συλλογή προέκυψαν νέα ερωτήματα που αναμένουν να απαντηθούν. Ποιος ήταν ο φωτογράφος; Υπήρχε μόνο ένας φωτογράφος; Πότε ακριβώς τραβήχτηκαν οι φωτογραφίες; Ποιος ήταν ο λόγος για την τεκμηρίωση συγκεκριμένων αντικειμένων; Αυτές οι ερωτήσεις είναι ένα ενδιαφέρον ζήτημα για περαιτέρω έρευνα, αλλά δεν αποκλείεται και να μην καταστεί δυνατόν να απαντηθούν ποτέ με βεβαιότητα.

Εν κατακλείδι, η διατριβή αυτή παρουσιάζει τα ακόλουθα συμπεράσματα που προέκυψαν από την έρευνα της φωτογραφικής ιστορίας της Βιβλιοθήκης της Αγίας Αικατερίνης.

Ο παράγοντας απόστασης και απομόνωσης της Ιεράς Μονής του Σινά έχει αποτελέσει το έδαφος για την ασφαλή φύλαξη των κειμηλίων ανά τους αιώνες, αλλά εξακολουθεί να αποτελεί πρόκληση για τους σύγχρονους ερευνητές που επιθυμούν να μελετήσουν τη Σιναϊτική Βιβλιοθήκη.

Με την πρόοδο της τεχνολογίας και ιδιαίτερα στον τομέα της φωτογραφίας, έγινε γρήγορα συνειδητή η σημασία της φωτογραφικής αναπαραγωγής ως μεθόδου διατήρησης των θησαυρών πολιτιστικής κληρονομιάς, όπως τα χειρόγραφα της Ιεράς Μονής Αγίας Αικατερίνης.

Η Ιερά Μονή του Σινά μπορεί να μην ήταν πάντα εύκολα προσβάσιμη, αλλά έχει καταβάλει σημαντικές προσπάθειες για την ανάδειξη των θησαυρών της μέσω της μελέτης και της πρόσκλησης μελετητών και φωτογραφικών αποστολών.

Η εφαρμογή της φασματικής απεικόνισης καθιστά αναγνώσιμα σβησμένα κείμενα και μαζί τους γίνεται και πάλι προσβάσιμη μια ξεχασμένη γραπτή ιστορία. Αυτή η πτυχή της ανακάλυψης αντικατοπτρίζει όχι μόνο την υλική ανάλυση των χειρογράφων ως αρχαιολογικών αντικειμένων, αλλά συμβάλλει επίσης στη μελέτη της κοινότητας των ανθρώπων που χρησιμοποίησαν, μετέφεραν και δημιούργησαν αυτά τα έγγραφα. Τα αρχαιολογικά κτίρια και κειμήλια της μονής είναι ένα ολόκληρο περιβάλλον που είναι τόσο αυτόνομο όσο και ευρέως συνδεδεμένο με ένα ανθρώπινο-πνευματικό οικοσύστημα.

Στη διαδικασία της φωτογράφισης και ψηφιοποίησης των χειρογράφων κάτι χάνεται. Η φυσική πτυχή των αντικειμένων και η αίσθηση της αφής δεν μπορούν να αναπαραχθούν με τα ηλεκτρονικά συστήματα (μέχρι στιγμής). Για να ξεπεραστεί εν μέρει αυτή η πρόκληση, πρέπει να καταγράφονται συνεπείς πληροφορίες με τη μορφή μεταδεδομένων.

Λέξεις κλειδιά:

Σινά, Μοναστήρι Αγίας Αικατερίνης, ιστορία της φωτογραφίας, ψηφιακή διαφύλαξη, ιστορία της έρευνας, χειρόγραφα, αναλογική φωτογράφιση, πολύ-φασματική φωτογράφιση, παλίμψηστα

Abstract

Saint Catherine's Monastery in the Sinai was built in the 6th century as a Byzantine fortress, protecting both the monks and their liturgical artifacts. The Sinai Monastery is characterized by its remoteness, isolation, and continuous monastic life in the last 15 centuries. These factors have greatly contributed not only to the formation of an ascetic spirituality, but also the preservation of treasured relics. Particularly, the Sinai Library is considered as second only to the Biblioteca Apostolica Vaticana in significance and number of manuscripts. The location of the Monastery has protected manuscripts from warfare and pillaging and the dry climate of the desert has preserved the objects in low levels of relative humidity.

This dissertation focuses on the photographic expeditions and projects that took place among the walls of the Sinai Monastery between the 19th and the 21st century. Divided in two parts, the first deals with the historical expeditions up to modern times (1894-2010). The second part investigates the most recent digitization projects (2011-2021) that include spectral photography of palimpsests, digitization of the entire Sinai manuscripts collection, and a forgotten 20th-century glass plates collection. This is the first time all documented photographic expeditions of Sinai manuscripts are investigated and described in one place. The historical aspect provides a platform of comparison and education from the experiences of different expeditions through different times. The technical dive into three modern digitization projects, all different from each other, gives a broad perspective on the contents of the Sinai Library collections. From erased and re-written texts to dry fragile parchment manuscripts, and forgotten glass plate photographs, the Sinai Library is a treasured research center. The concluding results of the dissertation offer new information based on research material not published before and contribute to the better understanding of the history of Saint Catherine's Monastery and its Library.

Keywords:

Sinai, Monastery of Saint Catherine, History of photography, Digital preservation, History of scholarship, Manuscripts, Analog photography, Multispectral imaging, Palimpsests

Introduction

The concept of bringing together parts of history is a journey into the unknown of events and lives of the past. Sometimes history is documented thoroughly, which makes the traveler more confident and safer; at other times, the journey is foggy and the researcher must be equipped with the torch of patience and stubbornness. Such is the case in studies of the history of Saint Catherine's Monastery and its Library (or the "Sinai Library"). With a history spanning 15 centuries, some periods are well documented while others require cautious investigation.

This dissertation investigates the history of the Sinai Library and its manuscripts, with a focus upon the photographic enterprises that have been devoted to the Sinaitic collection of manuscripts beginning from the 19th century: this topic has never been explored in its entirety. Its importance should be easily recognized, as photographic capture of manuscripts is an act of preservation that permits study of the object and its texts and illustrations. From 2011 until the time of this writing in 2021, I have worked in the Library as a photographer, as coordinator of large-volume imaging, and subsequently as researcher. Being able to touch the manuscripts as physical objects and at the same time operate sophisticated photographic equipment, I developed my interest not only in the history of the Library and the objects in it, but also in the experiences that I share with predecessors who undertook the same task of photography of the historical manuscripts. After all, I was not the first person to visit the Monastery with a camera. The idea of people traveling to a remote location under harsh environmental conditions with state-of-the-art technology is very intriguing and set in motion the research leading to this dissertation.

The significance of the Sinai Library is widely known among modern scholars through their personal trips to the Sinai or by examination of their publications. These sources can be summarized in catalogs of manuscripts including transcriptions of texts, catalogs with descriptive information of the physical object and photographs in various format (microfilms, slides, films, and digitized versions of the films). However, the task of the scholars is not easy, since the catalogs have been written in different languages (including Greek, Hebrew, Latin, Russian, Georgian, English, and French) for the 12 different languages of the manuscripts in the Sinai Library. Also, the photographic emulsions are deteriorating, and documentation of the expeditions whose members

gathered photographs is not always consistent or accessible to the public. These challenges, combined with the remoteness of the Sinai Monastery, are as significant today for any researcher as they were two hundred years ago.

In 2011, I was the photographer for the Sinai Palimpsests Project (SPP) organized by the Early Manuscripts Electronic Library (EMEL). In that role, I was responsible for the spectral imaging of more than 7400 erased and overwritten leaves of parchment. Since 2017, I have directed the digitization efforts of the Monastery (Sinai Library Digitization Project or SLDP) with the goal to make all of its manuscripts accessible online, both for research and educational purposes. My experiences and knowledge on the subject of manuscripts, palimpsested texts and scientific photography was enriched by my participation in many photography and scholarly projects around the world.¹

The more time I spent in the Sinai Library, the more my curiosity grew: How were photographs of manuscripts captured in the past? What kind of equipment did people bring to the Sinai desert? Why did they make these photographic expeditions? How did past expeditions resolve challenges connected to the remoteness of the Monastery? From where did these expeditions come and when did they happen?

My research aims to document past and present expeditions and projects that focused at preserving Saint Catherine's manuscripts through photography. To this end, I studied and extracted information from historical accounts, catalogs, facsimiles, and scholarly publications. In order to have a broad spectrum of information on the subject of my

¹ The author of this dissertation has participated for a decade (2011-2021) in such projects of small or large scale.

- Sinai Palimpsests Project at the library of Saint Catherine's Monastery (Egypt): 2011-2017
- Spectral imaging projects for the Museum of the Bible (U.S.A.): 2017, 2019
- Palimpsests imaging at the Matenadaran Scientific Research Institute (Armenia): 2018
- Codex Zacynthius and Cairo Geniza collection objects at the Cambridge University Library (United Kingdom): 2018
- The Jubilees Palimpsest Project at the Biblioteca Ambrosiana (Italy): 2017
- The Henoch Project at the Staatsbibliothek zu Berlin (Germany): 2016
- Scythica Vindobonensia (palimpsest Vind. Hist. gr. 73) at the Austrian National Library (Austria): 2016
- Palimpsests imaged at Friedrich-Schiller-Universität Jena Library (Germany): 2016
- Palimpsests imaged at L'Apostrophe - Mediatheque de Chartres (France): 2016
- Palimpsests imaged at the Centre for Manuscripts and the Ministry of Education and National Archives of Georgia, Ministry of Justice (Georgia): 2015
- Codex Vercellensis Recovery Project at the Capitulary Library of Vercelli (Italy): 2014
- Important Greek Witnesses in Vienna Greek Palimpsests at the Austrian National Library (Austria): 2013, 2016

research, I examined documents from archives of the institutions involved with the photography projects, as well as physical objects such as manuscripts, glass plate photographs and cameras from the last 100+ years. Through this journey, I came across erased texts containing forgotten medicinal recipes, neglected glass photographic plates, modern digitization equipment, bamboo sticks, and a lot of dust. I was also able to meet and exchange ideas with people, learn and share information through conferences, presentations, and publications. I have participated in several conferences and have presented parts of my findings (Kasotakis, 2017a, 2017b, 2018a, 2018b, 2021a, 2021b, Forthcoming).

My dissertation is divided into two main parts. Part One (*A Historical View of the Sinai Library*) is dedicated to the history of the Sinai Monastery, its Library, and of past photography projects, with the aim of setting the scene in space and time (location and history) in which so many people studied and touched the manuscripts of the Library. I aim to answer the questions, “what is the Monastery of Saint Catherine?”, “how and why was it established?”, and “how did it survive through the centuries?” Similarly, the chapter answers questions about the people and expeditions that visited the Sinai Library for the purpose of photographing manuscripts. This is the first time that the photographic material from the 19th century onwards has been brought together in one place. I present new information about major expeditions based on my archival research.

Part Two of the dissertation, *Modern Digitization Projects* (Chapters 2-4), deals with the most recent and current digitization efforts and has a more technical character, containing descriptions of three modern digitization projects in the Sinai Library. Chapter 2 (*Sinai Palimpsests Project*) is devoted to the spectral imaging of erased and re-written manuscripts called “palimpsests”. As part of the EMEL team undertaking this project, I photographed 74 manuscripts that allowed scholars to identify 307 unknown lost texts that were resurrected through the application of multispectral photography. The chapter deals with the concept of palimpsesting, past approaches of scholars to the erased texts, modern non-invasive methods of text recovery, and one example of an important recovered text: the recipe for phileterion, a plant that can be processed and applied on scorpion bites. Chapter 3 (*The Sinai Library Digitization Project*) focuses to the current digitization efforts of the Sinai Library. What are the challenges of a large-scale photography project in the middle of the desert? How is the

project structured? What equipment is used and why? Chapter 4 (*An Unknown Glass Plates Collection of the Sinai Monastery*) explores an unknown and forgotten collection of glass plate photographs. In this project, initiated with the support of Librarian Father Justin Sinaites, I cleaned, documented, digitized, and properly stored more than one thousand glass plates found in the Library of Saint Catherine's Monastery. Each of these technical chapters concludes with a summary of the most significant features of the projects.

Reflecting on the history of manuscript photography and the detailed analysis of the digitization process, a few general observations materialize. When transferring a physical object to a film reproduction or a digital form something is lost (researchers and students can no longer touch or feel the object). Parchment absorbs ink and is altered by environmental factors of low humidity and the passage of time. The recovery of the lost aspects of the source object is sometimes critical for the better study of the manuscript as a whole and not just its text. Differences in production and use of manuscripts can cast light into the undocumented history of Saint Catherine's Monastery and its Library. Therefore, these features must be documented without damaging the object. This study aims to present modern technologies of photography as a result of the lessons learned from the past and should be thought as a starting point for further development on the concept of data collection and not just plain photography.

Part One: A Historical View of the Sinai Library

1. History of Manuscripts Photography in the Sinai

The “Holy Monastery of Saint Catherine’s” in the Sinai Peninsula is considered one of the most important Christian monasteries in the world. At an altitude of 1500 meters and surrounded by granite mountain peaks with heights that exceed 2400 meters, the Monastery is a product of toil, perhaps stubborn toil of thousands of people over a period of 15 centuries. They erected granite walls, buildings and a church; they studied and prayed and they collected and preserved icons and other works of art and, over the centuries, created and preserved thousands of manuscripts in the dry Sinai climate that protected organic materials from rotting and disintegrating.

The triangular-shaped Sinai Peninsula between Africa and Asia is divided geologically into a relatively flat northern part and a mountainous southern part with numerous valleys (“wadis”). Bedouins of many specific belongings or “tribes” have lived there for millennia. Politically, it is part of the Arab Republic of Egypt and administered in a North and South Governorate. Saint Catherine’s Monastery is located in the center of South Sinai. (Figure 1.1)

The Monastery’s lasting importance is due to the early arrival of monks and visitors from the adjoining Christian meso-region and it has also attracted pilgrims over its 1500-year history, as indicated by inscriptions left on the 6th-century Justinian walls by Greeks, Syrians, Arabs, Georgians, and Latins. The area – distant from any center of power – was repeatedly invaded and conquered, but the monks in the Monastery received protection privileges, *firman*s (Persian) or *ferman*s (Turkish), beginning with the Muslim Prophet Muhammad. A *firman* is a decree or mandate from a Muslim ruling or authoritative person. In addition, a *firman* is socially protective for the monks – like the dryness of the desert is physically protective for the manuscripts. Subsequently, Arab and Ottoman sultans continued this tradition, followed by clerical authorities in Orthodox Russia and Greece, who also provided aid.

Over the centuries to the present, the Monastery has been an international pilgrimage site. Due to its unique architecture and treasures, protection by the Muslim *firman*s, its integration into the natural space, the continuous uninterrupted history of ascetic Christian life, as well as the sanctity of the area as recognized by the Christians,

Muslims and Jews, the Monastery has been included in the list of UNESCO World Heritage Sites since 2002 (UNESCO World Heritage Centre, 2002). Also due to the *firmands*, the Monastery has been under the protection of the neighboring Bedouin, a tradition that is preserved to this day by the Gebelea tribe, members of which are guardians of the main gate of the Monastery and who act as assistants of the monks in their daily works within the monastic compound. A mosque within the Monastery testifies to the mutual respect of the followers of the two religions.

The survival of the whole, and of the Monastery in particular, for a millennium and a half is due both to the devotion of Christian people, who choose to dedicate their lives to this arid spiritual location, and the protective Bedouins, as well as to the Egyptian state's archaeological service and charity from the world at large.

1.1 Saint Catherine's Monastery through the Centuries

The written history of the South Sinai begins with references in the Old Testament. When Prophet Moses led the people of Israel out of Pharaonic Egypt into the wilderness of South Sinai, he found a bush that burned but was not consumed. On nearby Mount Moses/Musa, the prophet received the tablets with the Ten Commandments inscribed. According to this tradition, the Israelites waited in the *wadi* for days before Moses returned from the Mount. During that time, some of the people constructed and began to revere a golden calf. Upon his return from the Mount, the angry Moses destroyed the calf. The sites of these events are marked today. The Monastery was built around the bush, which still thrives in the present. A mosaic in the apsis of its cathedral commemorates Moses receiving the tablets.

As early as the 2nd and 3rd centuries CE, Nabatean pilgrims carved Arabic inscriptions that have been dated to 149-253 A.D. by Bernhard Moritz (Migne, 1864, p. 217; Moritz, 1916).² In 330 CE, the East Roman or Byzantine Empress Helen (mother of Emperor Constantine) is considered by many to have funded the building of a small Church at

² Ancient inscriptions of Sinai are also mentioned by Kosmas Indikopleustis/Κοσμάς ο Ινδικοπλεύστης, «Ὅθεν ἐστὶν ἰδεῖν ἐν ἐκείνῃ τῇ ἐρήμῳ τοῦ Σιναίου ὄρους... πάντα τοὺς λίθους... τοὺς ἐκ τῶν ὀρέων ἀποκλωμένους γεγραμμένοις γράμμασι γλυπτοῖς εβραϊκοῖς ὡς αὐτὸς πεζεύσας τοὺς τόποις μαρτυρῶ» [There in the Sinai mountain...on the rocks...the ones fallen from the mountains written with engraved Hebrew letters as a testimony] (Migne, 1864, p. 217).

the site of the Burning Bush dedicated to the Virgin Mary. In addition, Helen is considered to have ordered a tower to be built to protect the hermits of the area. Parts of this tower have survived and have been integrated into the abbey of the Monastery.

As scholars know from extensive literature, a noble lady from Western Europe named Silvia or Egeria (also mentioned by the following names: Silvia, Silvania, Aetheria, Eucheria) and her escort of clergy undertook the arduous pilgrimage from Jerusalem to Sinai in 383 CE, a distance of twenty-two staging posts (Aetheria, 1948, pp. 16, 102, 110). In her report, she mentioned following an established route, for when they first caught sight of Sinai their guide told them, ‘The custom is that prayer should be made by those who arrive here, when from this place the mount of God is first seen’ (McClure, et al., 1918, p. 1). Silvia found at least 400 hermitages in the region and small churches at the top and just below the summit of Mount Horeb (or Horiv) dedicated to Prophet Elijah (or Elias), plus the one near the Burning Bush. The Elias chapel is still part of the Monastery’s outlying sites. The local monks brought fruits from their gardens for the benefit of the pilgrims, “*eulogia*” [offerings] in her words (McClure, et al., 1918, p. 5). By including the Greek words “*ascetis*” and “*eulogiae*” in her account, we understand that Sinai was an extension at the far reaches of the Holy Land and a part of the Greek speaking world from the 4th century CE.

In the 6th century, emperor Justinian ordered the construction of a strong fortress that enclosed the buildings of Empress Helen (by then sainted), in order to protect the monks of the region from raids. He commissioned the architect Stefanos Ailios to fortify the Monastery with strong walls and to erect a central church dedicated to the Virgin Mary. Justinian’s donation was meant to help the salvation of his soul and that of Empress Theodora, who had passed away. Thus, the donation was made between the years 548 CE (Theodora’s death) and 565 CE (Justinian’s death). Inscriptions with their names are found on the horizontal seventh and eighth ceiling beams from the west end of the central church. (Figure 1.2)

“† ΥΠΕΡ ΣΩΤΗΡΙΑΣ ΤΟΥ ΕΥΣΕΒΕΣΤΑΤΟΥ ΗΜΩΝ ΒΑΣΙΛΕΩΣ
ΙΟΥΣΤΙΝΙΑΝΟΥ”, “†ΥΠΕΡ ΜΝΗΜΗΣ ΚΑΙ ΑΝΑΠΑΥΣΕΩΣ ΤΗΣ
ΓΕΝΑΜΕΝΗΣ ΗΜΩΝ ΒΑΣΙΛΙΔΟΣ ΘΕΟΔΩΡΑΣ.” [To the salvation of the
pious King of ours, Justinian, and to the memory and the rest of the soul of our
beloved Queen Theodora.]

At this time, rooms were also built for the monks as well as for about 200 families from Pontus and Alexandria, who were settled to complete the buildings and to protect the monks. The families converted to Islam at the time of ‘Abd al-Malik ibn Marwan, the Umayyad caliph from 685 CE–705 CE (Caner et al., 2010, pp. 280–282). Procopius, the 6th century secretary of Justinian, wrote that the emperor provided some books for the monks of Sinai (Clark, 1953, p. 25). (Figure 1.3)

In the 7th century, Islam spread from the Arabian Peninsula outward to the Arab world. Christians and Arabs of the Sinai were Islamized, perhaps from deep conviction, perhaps merely in outward appearance. Prophet Mohammed’s followers generally respected the Monastery; the monks remained and pilgrims continued to visit. The Testament of the Prophet (*ahidnâme*), allegedly by Muhammad himself and ratified with the imprint of his palm, listed the privileges granted to the Monastery: Muslims were to leave the monks undisturbed in their duties, were not to collect taxes from them, and to defend them when need arose.

In 1935, an expedition from American archaeologist Harris Dunscombe Colt carried out a series of excavations in Nessana, a town in the Negev desert, which was the last important stopping point for travelers before they entered the al-Tih desert on their southward route. The expedition recovered hundreds of inscriptions dating from 464 to 630 CE, and hundreds of documents on papyrus dating from the early 6th century to 689 CE. All of the inscriptions are Greek, apart from a handful written in Nabatean Aramaic. The documents are also in Greek to the year 674 CE, when rulers begin to send letters written in Arabic to the local inhabitants, with an accompanying Greek translation. The documents from the local inhabitants continued to be written in Greek, even when addressing the rulers (Wasserstein, 2003, p. 260). Two of the documents are from a provincial governor named Abu Rashid, addressed to a Nessana administrator named George, requesting guides to Mount Sinai. Both are dated to the “twelfth indiction,” suggesting a date of 683/4 (Caner et al., 2010, pp. 266–267). These provide evidence for continued travel to Mount Sinai 50 years after the Muslim conquest.

We desire to know what happened at Sinai in the 8th, 9th, and 10th centuries, but the records are missing. This is the dark period of the Sinai’s history. The oasis at Wadi Feiran or Pharan, for example, was the centre of ecclesiastical, civilian, and military authority in the Sinai until the Arab conquests, then it vanished from record. Today, all

of its historical buildings lie in ruins. It is the same with the Monastery of El-Tor (or Raitho), an imposing complex built of white limestone in the 6th century. Its walls survive to a height of one or two metres, enough to allow archaeologists to reconstruct the layout of the Monastery. Who were the last monks of El-Tor? When did they leave? We do not know. In the absence of historical records, we must turn to material evidence to piece together the formal history of this period.

To summarize the further developments briefly: In the 8th century and because of its isolation in the desert, the Monastery became a diocese and then an archdiocese. This meant autonomy for its abbot. Under Muslim rule, with irregular connections to the Christian realm and to the archbishop of Jerusalem in particular, the abbot had to ordain deacons and priests for the spiritual needs of the Monastery, its dependencies in the Sinai Peninsula, and elsewhere. When the Ottoman Turks annexed Egypt with the Sinai in 1517, Tsernotas (Georgios or Ioannis, latter Ternota-beis – a Greek-cultured officer of the Ottoman Army, *hristiyan sipahiler*) ensured that the monks presented the *ahidnâme* to Sultan Sélim in order to secure the Monastery from the army pillaging, as well as to ask for further privileges. The Sultan had the original copy of the *ahidnâme* transferred to Istanbul. It is assumed that it still preserved there (“Tsernota-beis,” 2021).

In the 17th century the Monastery promoted cultural and educational activities beyond Sinai, especially in Greece, but also in the Venetian-occupied city of Heraklion in Crete as well as in other countries with dependencies of the Monastery, including Egypt, Turkey, Palestine, Romania, Russia, and India (Sarigiannis, 2010). Napoleon Bonaparte conquered Egypt in 1797-1804, and he, too, protected the Monastery. He ordered the rebuilding of the wall of the northern side of the Monastery in 1798, which had collapsed after a heavy rain. On the 8th of December 1798, he issued a special decree that ensured the monks’ privileges, free travel, and exemption from various financial burdens. With the macro-regional political changes in the second half of the 19th and the first half of the 20th century, the Monastery lost its properties in Russia, Romania, Turkey, Cyprus and elsewhere.

Today, the Sinai monastic community closely cooperates with the Egyptian as well as the Greek state. Both states, as well as private individuals and international institutions, are the Monastery’s great benefactors that ensure the safety and preservation of its cultural treasures. For these purposes, the Monastery cooperates with representatives of

the local government and of the archaeological service of the Sinai Peninsula, keeping in mind common issues of local, cultural or ecological policies.

1.2 The Library of Saint Catherine's or "the Sinai Library"³

The establishment of the archive and library began concurrent to the founding of the Monastery: When the buildings were completed, many gifts, including manuscripts, were sent to the monks (Clark, 1953, p. 25). Later, Byzantine emperors also sent gifts and precious manuscripts. For example, Sinai Greek 204, which contains readings from the Gospels, is characterized as an imperial gift of the 10th century; Sinai Greek 207, which contains Evangelical readings for the whole year and whose parchment is of excellent quality, was manufactured and written in the 12th century. Historian Konstantinos Amantos listed donors and benefactors, especially the Komnenoi dynasty (1081-1185), the Emperor John III Vatatzes of Nicaea (1222-1254) and the Emperor Michael VIII Palaiologos (1259-1282) (Amantos, 1928, 1953). Patriarchs and other clergy also donated manuscripts and letters: one example is Philotheos Kokkinos (1353-1376) (Glykeis, 1817, p. 167). Furthermore, lay people from many parts of the world have enriched the Library with donations.

Of course, ascetics and monks in the Sinai also wrote or copied manuscripts and letters. For example, Saint Neilos of Sinai of the 4th century, who had been a resident of Constantinople and a prefect, wrote numerous ascetic speeches and letters while a monk in Sinai, many copies of which are in the Monastery's Library (Tsamis, 1989, pp. 239–355). Moreover, in the 5th and 6th centuries, Saint Nikon of Raitho (El-Tor) and Theodoros of Raitho wrote works that were studied for a long time (Nikas, 1981).

The original location of "the Library" within the Monastery cannot be determined. Before the 18th century, we know that the Sinai manuscripts and printed books were kept in three different areas. Copies of the Gospel and other books necessary for the services were kept in storerooms adjoining the church, or in cabinets within the church, as is the practice to this day. Other books were kept at a central location, from where a monk could take a book to read it.

³ Summary of the Sinai Library history can be found also in (Rossetto, 2019, pp. 17–39).

In the Sinai archives, the following decision was recorded on April 15, 1776. This is note is found in manuscript Sinai Greek 2197, p. 452.

On this day, Pachomios of Rhodes departed for the school of Patmos in order to study. We gave him from the Centre six separate books for his lessons: Lucian, Herodian, Xenophon, an Encyclopedia, the first volume of an Encyclopedia, and a large old Horologion, and when he has returned here, they should be placed back in the Centre. (Rossetto, 2019, p. 25)

The third location was the Tower of Saint George, which projects from the north wall of the Monastery. The oldest and most fragile manuscripts were kept here in a storeroom at the second storey level which could only be reached by an internal ladder, thus one of the most secure parts of the Monastery.

Due to the ascetic nature of monasticism in Sinai, small libraries with few books also existed in many of the scattered hermitages in the mountainous area. The hermits and small communities of monks would celebrate the Sunday liturgy at the main Monastery but would live outside of the fortress walls. From the 8th to the 13th century, more than 1700 hermitages in Egypt were destroyed, so it is assumed that manuscripts from these small libraries were transferred to the main Monastery fortress (Clark, 1953, p. 26). Later, in the time of Ioasaf (Archbishop of Sinai 1617-1660), though perhaps earlier, many of the precious manuscripts and other objects were kept in “Middle” (Μέση), a place in the Monastery near the mill, which is used today for storage of food. Subsequently Archbishop Kosmas (1702-1707) used various storage spaces. When Michael Eneman from Uppsala visited in 1712, at the time of Archbishop Athanasios III (1708-1720), a site along the wall and near the central Church was used for the Library. Eneman’s description of numerous Arabic, Ethiopic and Syriac manuscripts is the first written account of the Library. Jesuit scholar Claude Sicard noted in 1715 that monks often moved the manuscripts. The reasoning they gave was that manuscripts were missing after the departure of many visitors. Even after this complaint, Sicard managed to take manuscripts back with him for the King of France (Clark, 1953, p. 27). By the early 18th century, manuscripts were kept in the “Katholikon”, the “Middle” (or Mesi), as well as storerooms along the walls.

The concept of a special building for the protection and use of manuscripts dates to Nikephoros Marthales Glykys, Archbishop of Sinai from 1728 to 1747. He can be

considered the founder of the modern Library: he was the first to gather all of the books and manuscripts into one central location. He was both a skilled calligrapher and binder of manuscripts.

When he was elected Archbishop of Sinai in 1728, he had a great concern for the Library, and ordered that new rooms opposite the Archbishop's quarters be set aside for the books and manuscripts. He himself wrote:

Seeing the books dispersed, some in cabinets, others in chests and cells, we felt for them and appointed to the Synaxis, as overseer of the books, the most educated holy teacher and Protosynkelos kyr Isaias, who with much labour and diligence gathered all the books and catalogued them and placed them appropriately, as can be seen now in the library, which was built with much care by the monk Hadji Philotheos, together with the craftsman kyr Symeon the elder, and all the present brotherhood. (Pantelakis, 1939, p. 108).

The inscription carved above the central doorway reads:

This library was built with the supervision and help of the Most Reverend and Most Pious Archbishop of Mount Sinai Master Nikiphoros, the work of the builder Philotheos monk of Sinai, and Symeon. Ye who read, remember them.
1734. (Rabino & Runciman, 1938, pp. 49, 110)

Since manuscripts and rare printed books had been "lost" when visitors had been given permission to look at them, stricter control was exerted. For example, during his visit to the Middle East in 1739, the English-born clergyman and scholar Richard Pococke managed to enter the Library, but was not permitted to study any manuscript (Clark, 1953, p. 28).

In 1761, the Italian pilgrim Vitaliano Donati saw in the Library a huge number of parchment manuscripts in various languages, esp. Greek, Arabic and Syriac (Clark, 1953, p. 27). Among them, he recognized a Bible codex from the 4th century written in majuscule Greek on parchment. He was perhaps the first visiting scholar to distinguish the now-famous "Codex Sinaiticus," which may have been among the first gifts after the Monastery's founding. In the 19th century, the contacts between the Orthodox Monastery and western Christian scholars – rather than pilgrims – intensified. For example, as early as 1815 – immediately after the end of the Napoleonic wars – Lord W. Turner visited the Monastery but was not allowed to study the manuscripts.

Thereafter, numerous traveler-scholars visited and gave widely diverging estimates of the number of the manuscripts and printed books in the Library. In the same year of 1815, English explorer William John Bankes counted 1500 manuscripts (1350 in Greek), as well as 500 printed books. In the years between 1810 and 1840, we have the following accounts for the library: Jean-Jacques Rifaud an explorer from France, described the library as unimportant with only few materials. Did the monks not show him their treasures, or did he want to disparage the value of the library? Ferdinand von Geramb (or Maria Joseph von Geramb) from France, in contrast emphasized the importance of manuscript collection and Johann Ludwig Burckhardt from Switzerland, counted 1500 Greek and 700 Arabic manuscripts (Clark, 1953, pp. 27–29; Volkoff, 1972, pp. 125–171). As with Rifaud, similarly the Russian A. Oumanetz, during his visit in 1842-1843, describes the Library as “a small section lined with books” (Benešević, 1937, p. 22). The systematic and successful efforts to catalogue manuscripts began with the visit of the Smith sisters from Scotland in 1892 (see below) – their catalogue is still used by scholars in the present. In the discussion of the present preservation and digitization projects in Chapter 2 and 3, the scholars established a “controlled” process of comprehensive cataloguing including metadata. But the wide variety of complete codices, torn-out quires, single folia and folio fragments is still challenging scholars in the present.

During an expedition in 1840, Kyrillos, a librarian from Mount Athos, made the first significant attempt at cataloguing. He indiscriminately listed about 1500 manuscripts and printed volumes. At about the same time, Archimandrite Porphyrios Uspensky made repeated visits to secure descriptions of numerous manuscripts selected from the Greek collection, though these were never published until used by Vladimir Benešević (Benešević, 1912). In 1870, Antonin Kapustin visited the Monastery and catalogued 1310 Greek manuscripts, 500 Arabic, 38 Slavic, and some Syriac. He is reported to have taken a photographer with him and this may have been the first use of photography at the Monastery.

The monks’ precautionary measures against removal or theft of manuscripts proved insufficient. In 1843, the German scholar Constantin von Tischendorf visited Egypt and Sinai for the first time. During his research at the Library, he removed 43 folia from Codex Sinaiticus and transferred them to Leipzig. Two years later, the Russian archimandrite Porphyrios Uspensky admired the precious old manuscripts and removed

several folia which he brought to Saint Petersburg (Benešević, 1912). Worse was to come: Tischendorf returned to Sinai in 1853, showed great interest, counted about 1000 manuscripts, and began negotiations to “borrow” the Codex Sinaiticus. He finally succeeded in 1859 with the help of the Russian Ambassador to Cairo, Lovonov. The Codex was never returned (Ševčenko, 1964, pp. 55–80).

At the beginning of the 20th century, the buildings along the south wall of the Monastery were in a poor state of repair. It was decided to demolish them and construct a new building, which was to provide a better place for the Library. The old buildings were torn down and the site cleared in 1930. The new building was designed by the Greek architect P. Frangoulis. The building consists of a reinforced concrete frame with load bearing masonry. There was no electricity in the Monastery at the time, and it was difficult to transport construction materials through the desert. Construction was hampered by a lack of funds, and then interrupted during the Second World War. The new south wing was only completed in 1951 and the Library was moved to the east end of the top floor. The manuscripts and early printed books were kept in one great hall, with the manuscripts at balcony level, and the early printed books at the lower level. A separate room contained the collection of modern printed books. These quarters were a great improvement over the many small rooms that had served to house the Library before. But in more recent times, there was a desire to bring the Library building up to more modern standards. A remodeling could improve the environmental stability of the Library, with additional features for fire protection and security. The result would also be a more beautiful space for the housing of the Sinai Library.

The Saint Catherine Foundation invited Dimitri Porphyrios of Porphyrios Associates in London to the Monastery in 2005 to provide the Monastery with an aesthetic design for the new Library. The implementation studies were entrusted to a team of architects and engineers under the direction of Petros Koufopoulos from Athens. Nicholas Pickwood, a respected conservator from England, helped to plan the new Library. It was decided to have the manuscripts at the lower level, where they would be more accessible, with the balcony reserved for early printed books. It was also decided to store all manuscripts at the lower level on horizontal racks that would accommodate stainless steel cases. These will provide fragile manuscripts with the protection they require, without the need for further intervention or conservation, thus preserving their historical integrity.

Thanasis Velios, a computer programmer working in the UK, wrote a special program to plan the best use of the available space. (Figures 1.4, 1.5, and 1.6)

1.2.1 The History of the “New Finds” Collection

When a fire broke out in the north-west corner of the Monastery in 1971, the flames were quickly extinguished, but the beams within the Tower of Saint George, which projects from the northern wall of the Monastery, had been damaged. This caused part of the ceiling to collapse into a room that had been hidden from the sight and memory of the monks for centuries. Repair and renovations in 1975 revealed a cache of some 1500 fragments of manuscripts in thirteen different languages, the most important manuscripts find of recent times. The reasons for the separation of these manuscript leaves from the bulk of the collection in the Old Library and the Church are still not clear. Possibly they were discarded as no longer of use. A first review of these “New Finds” were officially presented by the Abbot of the Monastery, Archbishop Damianos, at the International Congress of Byzantine Studies in Vienna in 1981 (Hunger et al., 1982a, p. 50, 1982b, p. 116). Thereafter, the systematic cataloguing of the New Finds began, including determination of the number of palimpsests. (Figure 1.7)

1.3 Manuscript Photography in the Sinai from the 19th Century

In this section, I will list and describe the various expeditions that took place in the Sinai Monastery from the 19th to the 21st century for the purpose of photography of the manuscripts. My research is based on published and unpublished sources, including the Sinai Monastery archive, declassified documents from the U.S. Library of Congress, private communications with the National Library of Israel. The expeditions are listed in chronological order.

1.3.1 1889 - James Rendel Harris

James Rendel Harris (1852 - 1941)⁴ was an Anglo-American who studied at Plymouth Grammar School and then at Clare College, Cambridge. From 1882 to 1885, Harris was Professor of Greek New Testament at Johns Hopkins University. From 1886 to 1891 he was a Biblical Studies Professor at Haverford College, near Philadelphia, Pennsylvania. In 1888 and 1889, Harris donated 47 codices brought from Egypt and Palestine to Haverford College (Falcetta, 2020, pp. 410–411). During his visit at Saint Catherine’s Monastery in 1889, Harris discovered a Syriac text of the Apology of Aristides and took photographs of various leaves of the Syriac and Arabic manuscripts using a Kodak camera and celluloid film (Harris, 1890).⁵ In 1894, he again visited the Monastery together with Agnes Smith Lewis and Margaret Dunlop Gibson. He described additional fragments and published them in the appendix of their catalogue (Lewis, 1894, pp. 95–123). Harris described and published in total 71 Biblical fragments: 16 in 1890 and 55 in 1894 (Velkovska, 2013, pp. 223–252).

1.3.2 1892 - Agnes Smith Lewis and Margaret Dunlop Gibson

Agnes Smith Lewis and Margaret Dunlop Gibson were twin sisters from Scotland who, inspired by the travels of Rendel Harris, visited Sinai in 1892. Before their trip, Rendel Harris trained them in the use of his camera. They purchased the same model of camera and film for one thousand exposures before their visit to the Monastery. They also brought with them a stand designed by Rendel Harris based on his experiences in the Sinai Library to hold manuscripts while being photographed.

After arriving in the Monastery in February 1892, Agnes S. Lewis was particularly fascinated by an old Syriac manuscript. She immediately saw the value of it and notified the librarian and her sister that they should image it in its entirety. At first, Margaret Gibson was hesitant to expend a third of their film reserves on a single manuscript. After careful study, they determined that the object was a palimpsest, an object they

⁴ The middle name is often misspelt “Rendell”.

⁵ This detailed information on technology and materials used is necessary for all later scholarly attempts to use the photographs as sources.

had only heard of from their father, who had never been to the Sinai but would often say stories:

...of how the old monks, when vellum had become scarce and paper was not yet invented, scraped away the writing from the pages of their books and wrote something on the top of it; and how, after the lapse of ages, the old ink was revived by the action of common air...(Agnes Smith Lewis, 1898, p. vii).

The top layer of the palimpsest includes lives of female Christian saints. The erased undertext is a copy of old Syriac Gospels. The object came to be called “Syrus Sinaiticus” (Sinai Syriac 30), one of the most important manuscripts of the collection (Gibson & Lewis, 1893, pp. 60–67).

The Scottish sisters prepared the first catalogues of Arabic and Syriac manuscripts, still valid and used by scholars until today (Gibson, 1894; Lewis, 1894). They were the first scholars who saw value in photographic reproductions of the original object for purposes of study. Not only did they *not* remove the manuscripts from the Library, but they returned a “missing” book found in the markets of Cairo and recognized to be part of Saint Catherine’s collection. Even so, lacking the advanced technology of modern spectral photographic systems, they applied destructive techniques popular among scholars at the time to assist their readings of the undertext of the manuscripts. Their approach to the palimpsest text of Sinai Syriac 30 is reviewed in Chapter 2.

1.3.3 1907 - Vladimir Nicolaevič Beneševič

The Russian Byzantinist Vladimir Beneševič (1874–1938) traveled to the Sinai in 1907 for the first of his three visits. At the time, Beneševič possessed the notes that the Russian archimandrite Porphyrius Uspensky (1804–85) took during his visits in 1845 and 1850 (Thomson, 2003, pp. 305–316; Dmitrievskii, 1856, pp. 21–171), as well as the handwritten catalogue from 1870 by the Russian’ archimandrite Antonin Kapustin (1817–94) (Dmitrievskii, 1856, pp. 393–452; Parpulov, 2011, pp. 34–42). These notes greatly facilitated Beneševič’s photographic work. By 1907, scholars understood the benefits of capturing information about the object’s appearance with the help of photography instead of just transcribing the texts onsite. In the Sinai Monastery, Beneševič used a camera designed specifically for manuscript photography. By 1912, he published an album of his work along with notes, and subsequently a second one in 1925. These albums benefited the scholarly community for the next 70 years. After this

time, more recent photographic efforts at the Monastery in form of microfilming were made (Benešević, 1912, 1925; Hatch, 1932; Harlfinger et al., 1983; Weitzmann & Galavaris, 1990).

1.3.4 1914 - Carl Schmidt and Bernhard Moritz

In 1914, the Prussian Academy of Sciences generously financed an expedition of two eminent German scholars to the Sinai Library, Carl Schmidt (1868–1938), a Patristics scholar, and the Arabist Bernhard Moritz (1859–1939). The initiative to this expedition was of Archbishop Porphyrios II (1859–1926) who had studied in Göttingen and Leipzig between 1890 and 1894. The experience of his studies later induced him to invite Schmidt to compile a catalogue of the Monastery's Greek and oriental manuscripts.

Before his expedition, Schmidt was assisted by the notes and photographs of Benešević, who had visited the Library repeatedly over seven years. Upon arrival, the German scholars photographed around eight thousand images of manuscript folia in a time span of four months. It was in August of the same year of 1914 that they departed the Monastery, only to find out the news of the World War that had eluded them in this remote location. This seclusion had permitted the Monastery to survive through the centuries (Schmidt & Moritz, 1926, pp. 26–34).

All of their photographic equipment and thirty cases of glass plates were left with the German consul, M. Georg Meinecke, in Suez. Twenty-five of the boxes disappeared as they were deemed “war contraband” by the British. Five boxes were sent to Cairo and some 1500 images found their way to the Biblioteca Apostolica Vaticana through the Italian vice-consul of Suez Isidoro Giannelli, who gifted them to Monsignor Mario Boehm of the Osservatore romano (Piazzoni & Jatta, 2010, p. 173). Most likely their photographic equipment and most of their records ended up being captured by the British and subsequently destroyed.

Unfortunately, from the results of many months of arduous work all that survived for Schmidt and Moritz were the handwritten notes that they carried with them in their luggage, but with the photographs lost, they were insufficient documentation.

1.3.5 1923 – William Henry Paine Hatch

The American New Testament scholar William Henry Paine Hatch traveled to the Sinai Monastery in 1923 with the goal of examining and photographing Greek manuscripts. Hatch, a professor at the Episcopal Theological School in Cambridge, Massachusetts (1917–46) accepted an annual teaching position at the American School of Oriental Research in Jerusalem for the years 1922-1923. From there he traveled to the Sinai Monastery with the support of Mary B. Longyear and the Zion Research Foundation of Brookline in Massachusetts.

The expedition to the Sinai was launched in January 1923. Hatch was accompanied by his wife and son, as well as Rendel Harris, Herbert G. Wood, and twelve more people from the United States, Jerusalem, and England. The group traveled by steamboat until El-Tor from where they continued their journey on camels. Under the protection of a Sheikh from the Tawarah Bedouin tribe they reached the Monastery after three and a half days. There, they camped for three weeks outside the walls.

Hatch notes that the monks “treated them with utmost kindness and allowed them to work in the library every day except Sundays and feast days” (Hatch, 1932, p. 9). But they were informed that photography of the manuscripts would not be possible without authorization from the archbishop who was in Cairo. The group sent a messenger to El-Tor carrying a telegram for the Archbishop in Cairo. Four days after they received a positive response. Photography was carried out by Lewis Larsson, a member of the American Colony in Jerusalem, who was also the Swedish consul in Jerusalem. The result of the expedition was the study of 77 Greek minuscule manuscripts of the New Testament. Photographs from each manuscript along with a detailed description was published in 1932 including two manuscripts unknown to scholars at the time. (Hatch, 1932, pp. 8–11)

1.3.6 1928 - Arthur Hjelt

The Finnish theologian Arthur Hjelt traveled to Sinai in 1928 for the purpose of photographing the palimpsest manuscript Sinai Syriac 30 in order to produce a facsimile. Hjelt was aware of the presence of palimpsested folia in the specific manuscript from the publications of the Smith sisters and came prepared with a photographic camera and specially coated glass plates to take advantage of the effects

ultraviolet light had on the erased text. Hjelt was partially successful since there was no electricity in the Sinai to support some of his photographic equipment (Chapter 2.2).

Following his Sinai visit, Hjelt published two major works. The first was “Helsingistä Siinaille” (Hjelt, 1929), a detailed record of memories of his trip from Finland to Saint Catherine’s Monastery with pictures. The second work was the facsimile of Sinai Syriac 30 “Syrus Sinaiticus: Codex Palimpsestus Sinaiticus” (Hjelt, 1930). Even if the facsimile does not help make the undertext legible, it does show the changing trend in the early 20th century in the use of more specialized technologies in the service of cultural heritage studies and preservation.

1.3.7 1950 - Library of Congress⁶

In 1950, following prolonged negotiations dating from 1948, the request of the U.S. Library of Congress in Washington (LoC) to photograph the majority of manuscripts in Saint Catherine’s Monastery were granted by Archbishop Porphyrios III.

The orchestrator and driving force of this project’s first steps was Wendell Phillips. His first connection with the Middle East was through the participation in archaeological trips in the 1940s with the University of California Africa Expedition (Phillips, 1948, p. 666). In 1948, he founded the American Foundation for the Study of Man, Inc., which included important board members such as the U.S. Navy Admiral Chester W. Nimitz and the Vice President of Pan American Airways, Samuel Pryor. Having a strong record on raising resources, Phillips spearheaded the approach and negotiations with the leadership of Saint Catherine’s Monastery on behalf of the LoC, after the suggestion of W. F. Albright, professor at John Hopkins University. Phillips’ approach to the Monastery was greatly supported by Ioannis Trikoglou, a Greek businessperson in Egypt and personal friend to the Archbishop Porphyrios III. The adventurous negotiations of Phillips even included the gifting of a golden revolver to His Majesty King Farouk of Egypt in order to gain favour and apply pressure to the Sinai community of monks. He also traveled to Istanbul to meet with His Holiness Athenagoras I,

⁶ The following is based on unpublished material from the archives of the Library of the Sinai and the Library of Congress, unless differently indicated by the in-text citations.

Patriarch of the Greek Orthodox Church, in order to secure recommendation letters for his visit to the Sinai Monastery.⁷

The project agreement between the LoC and the American Foundation for the Study of Man was signed on December 2, 1949. Kenneth W. Clark, professor at Duke University, an expert on Greek-Christian manuscripts, was appointed as the head scholar of the onsite mission. Clark was accompanied by Aziz Atiya, Vice Dean of the Faculty of Art of Farouk University in Alexandria (Egypt), appointed to record the Arabic documents of the Sinai Monastery. For the Georgian and Armenian manuscripts Gerard Garitte, professor at Louvain, Belgium, joined the expedition. The director of photography was Wallace Wade of the LoC staff.

On January 5, 1950, the team of about twenty persons (six Americans, a Belgian, and five Egyptians, who formed the core staff, besides other Egyptian and Greek associates) each with his own special assignment, arrived in four automobiles that had been especially equipped for desert travel.⁸ They carried with them two gasoline generators and heavy cable, three microfilm cameras with book boxes, a 4" × 5" viewing camera, and over one thousand rolls of microfilm. The photographers worked seven hours per day, six days a week. The three microfilming cameras had a daily average capacity of 25 manuscripts (depending on the number of leaves) and 300 *firman*s. In the course of seven months, the entire Library was examined. However, from the approximately 3300 manuscripts, only 1687 were photographed, as it was quickly understood that it would be impossible to photograph all in the given time frame.

Priority was given to the older manuscripts and the ones of the Scriptures. The project photographed the extensive collection of *firman*s in Arabic and Turkish. The team also made 4" × 5" black-and-white transparencies of all the manuscript illuminations, resulting in 116 miniatures imaged (Clark, 1953, pp. 22–36). Because of the large volume of images, rolls of film would be sent back to the LoC, developed, and then

⁷ Unpublished communication between Wendell Phillips (American Foundation for the Study of Man) and Luther Evans (Library of Congress) on August 2, 1949. Preserved in the Library of Congress Archive.

⁸ Staff List for The American Foundation Mount Sinai Expedition: William Terry, Gladys Terry, A.S. Atiya, Kenneth Clark, Wallace Wade, Howard C. Kee, Mrs. Kenneth Clark, A. Abbadi Bey, Yassa Abdel Massih, Ahmed Issa, Mahmoud Nefei, Ibrahim Sabri, Gerard Garitte, Murad Kamil. From unpublished communication of Wendell Phillips to Verner W. Clapp on November 14, 1950. Preserved in the Library of Congress Archive.

notes about retakes were returned to the onsite team. To this end, Professor Atiya played a critical role in the success of the project, not only by securing the whole-hearted cooperation of the Egyptian authorities, but also by making arrangements so that rolls of film would be shipped in diplomatic pouches of the Egyptian Government to the Egyptian Embassy in Washington.⁹ In September 1950, the final shipment of films from Saint Catherine's Monastery reached the LoC.

Following the photographic expedition, a bitter turn of events damaged the relationships between the Monastery and the LoC. The Monastery requested copies of the films, referring to promises made by the American Foundation of Phillips during negotiations in 1949. The LoC replied that these were "commitments which the Foundation may make," but by which it was not bound. To the LoC, all commitments were understood to be fulfilled with the delivery of copies of the films to Alexandria University in Egypt. LoC also argued that the \$10,000 that the Monastery received was a gift that fulfilled all commitments regarding the project. In internal communications, LoC members noted that a copy for the Monastery would be very expensive to make and the monks would not need one "since the Monastery has the original objects in its possession." Eventually, the entire microfilm collection was digitized and made available online by the LoC in the 21st century (Library of Congress, 2012).

1.3.8 1956 - Universities of Michigan and Princeton

Between 1956 and 1965, five expeditions were sponsored by the Universities of Michigan (U.S.A.), Princeton (U.S.A.), and Alexandria (Egypt), with the goal of documenting the history of the art and architecture of the Monastery of Saint Catherine (1956, 1958, 1960, 1963, and 1965). George H. Forsyth from the University of Michigan was an archaeologist, architect, and art historian who made precise drawings of all the buildings within the Monastery. He was the director of the expedition and focused on the Monastery's wood and stone sculptural reliefs. Through his work he was able to trace stages of the architectural development.

⁹ Unpublished communication between William B. Terry (American Foundation for the Study of Man) and Verner Clapp (Library of Congress) on February 7, 1950. Preserved in the Library of Congress Archive.

Forsyth invited Kurt Weitzmann from Princeton University to collaborate by leading the photography and study of all historical and medieval icons. As an art historian, Weitzmann was interested in both icons and manuscript illuminations. His interest in the Sinai manuscripts was recorded during the expedition of the LoC in 1950, when he had requested the photography of manuscripts with “miniatures” and expressed intent of purchasing the photographic negatives that would be created. During his own expedition to the Sinai, he again photographed the manuscript illuminations using modern film cameras that could provide the details of these small miniatures in color. His photographic approach to this category of manuscripts greatly supported his study on the history of Christian art. In his work, he was supported by Ihor Ševčenko, an Ukrainian born in Poland and professor of classical philology at Harvard University, who studied inscriptions and manuscripts.

The head of photography was Fred Anderegg from the University of Michigan, who captured images of the structural aspects of the Monastery, as well as icons, mosaics, and manuscripts. The photographs allowed for the study of the Sinai treasures by many scholars and art historians around the world.

From 524 selected manuscripts, 2000 photographs were captured, followed by publication of over 700 illustrations (Dumbarton Oaks, 2008). Manuscript descriptions were accompanied by paleographical and codicological data. Information on the bindings, condition, history, illustrations, and style of each item was recorded along with a supporting bibliography for each (Weitzmann & Galavaris, 1990).

For the photography of the icons, in total 3244 photographs were captured on 5" × 7" Ektachrome Kodak transparencies (1249) and 35mm slides (1995). Some icons were photographed multiple times to capture different details.

The expedition also undertook an emergency consolidation of the Sinai apse mosaic (presenting the Transfiguration of Christ) in 1959, as signs of deterioration were observed and a potential risk of collapse. Subsequently, in 1960, the team worked on a preliminary cleaning of the mosaic. This preservation work was undertaken by Ernest Hawkins, Carroll Wales, Paul Underwood, as well as Robert Van Nice who was part of the architectural survey.

The slides and transparencies of the icons that were created by the expedition have recently been digitized by Princeton University (Princeton University, 2017).

1.3.9 1969 - National Library of Israel¹⁰

In 1968, Bathja Bayer, director of the Music Department at the National Library of Israel, published a checklist of the known manuscripts at Saint Catherine's Library (Bayer, 1968). Her work expanded on the checklists of Kenneth Clark and for the microfilming of LoC in 1950 by including all known manuscripts of the Sinai Library. Unfortunately for the scholars outside of her institution, the checklist was meant only for internal distribution to the Jewish National and University Library of Jerusalem.¹¹ Her main interest in the collection was of the Monastery's musical manuscripts. In her proposal, she suggested a small-scale microfilming project: "*The team should be as small as possible, preferably one microfilm machine and one photographer, to be augmented whenever conditions permit.*" The photography project took place between 1969 and 1970 with a few imaging sessions of about three months each.

In 1969, Malachi Beit-Arié, head of the Jewish National and University Library's manuscripts department (today's National Library of Israel), proposed continuation of the microfilming for the remaining of the manuscripts that had not been imaged by the LoC in 1950, meaning mainly manuscripts which were copied from the 12th century onwards. Beit-Arié was initially skeptical that the Monastery would not allow such large-scale project, since the Sinai Peninsula had been captured by Israeli forces during the Six Day War only two years earlier in 1967. Archbishop of Sinai Grigorios II, who had studied Hebrew, was unexpectedly receptive to the idea of this collaboration. Shortly after negotiations, a Memorandum was signed on June 6, 1969. This memorandum was simple but clear and serves as an example of the bitter memories in the Monastery of the LoC microfilming project. Of the seven agreed points, three referred to the produced microfilms and the Monastery's ability to have access to them (*Sinai Archive, Folder 327, 1969*).

¹⁰ The following is based on unpublished material from the archive of the Library of the Sinai and private communication with scholars and employees of the National Library of Israel, unless differently indicated by the in-text citations. Personal communications with Daniel Lipson, Reference & Digital Resource Librarian; Milka Rubin, past curator for General Humanities; Stefan Litt, curator for General Humanities; Shai Ben-Ari, Chief Editor & Writer; Israel Weiser, former NLI employee.

¹¹ Many of the numerous checklists mentioned above were in different languages (Greek, Hebrew, Latin, etc.), sometimes not accessible to many scholars, or were lost.

- A copy of all films made would be sent to the Monastery as soon as possible.
- At the completion of the project, the microfilming reader used by the project will be gifted to the Monastery.
- A 100 per cent surcharge would apply to foreign institutions purchasing NLI microfilms of the Sinai manuscripts, in order to finance the obtaining of LoC microfilms for the Monastery.

Two photographers were employed and travelled onsite, the contractor Jacques Soussana (main photographer) and his assistant. Two cameras were installed at the site: a Kodak Recordak, which used on both sides perforated 35mm × 30m microfilm, and a Koni Omega microfilm camera which used unperforated microfilm. The photographers used two types of films: Kodak Recordak AHU and Agfa Copex Pan AHU, panchromatic black and white microfilm on cellulose acetate base. Electricity was supplied by two (military) field generators, which caused many problems due to the unstable electrical voltage. Due to the fluctuations in the lighting intensity, microfilm frames of different densities were obtained (density variation out of standard). One of the two generators was donated to the Monastery upon completion of the project.

Israel Weiser, an electronics-engineering student that worked at the National Library as part of the laboratory staff for developing and copying microfilms, in this capacity worked to repair defective shutters onsite in Sinai and to develop/copy microfilms in Jerusalem. He recalls that the team worked four hours a day, five days a week (excluding Saturdays and Sundays). Weiser also notes that, due to the limitation of the microfilm to separate shades of gray (only 18-19 instead of 255 in modern digital signals), a short attempt was made to photograph the pages of the manuscripts with damaged script in different modes. Photographer Rafi Magnes used a special infrared (IR) film, but the results were not good enough to suggest continuing this kind of photography.

The project continued until its completion in 1972, building a strong bond between the Monastery and the Israeli academic community. After 50 years, most film reels were damaged by symptoms of vinegar syndrome (Feller, 1994). Over the past years (2017-2020), microfilms collected by the expedition of some 1700 manuscripts have been

digitized and made available online through the Library's Merhav catalog (*The National Library of Israel*, 2021).

1.3.10 1975 - National Library of Greece

Following the discovery of the "New Finds" collection in 1975 (Chapter 1.2.1), the Monastery of Saint Catherine's invited the support of the Greek state in organizing the extremely fragile objects. The call was answered by Panagiotis Nikolopoulos, Director of the Manuscripts Department of the National Library of Greece (NLG), and Vasilios Peltikoglou, Director of the Manuscript Conservation Department of the NLG. With the support of the Greek ministry of Foreign Affairs, the National Library of Greece and the Sinai Monastery embarked in a multi-decade long journey to preserve, classify, and microfilm some 1500 new objects and thousands of fragments.

Manuscripts were grouped by language and subsequently by substrate material. Following categorization and counting, manuscripts were cleaned and put into individual paper folders. For the storage of thousands of fragments, 167 cardboard boxes were made with a fabric enclosure that was sewed in the Monastery (42cm high × 28cm long × 12cm wide).

Table 1.1

Groups of New Finds manuscript shelfmarks as they exist today in the Sinai Library

Manuscript groups

Arabic New Finds parchment
Arabic New Finds paper
Georgian New Finds parchment
Georgian New Finds paper
Georgian New Finds scroll
Greek New Finds majuscule
Greek New Finds minuscule paper
Greek New Finds minuscule parchment
Greek New Finds scroll
Slavonic New Finds
Syriac New Finds parchment

Parchment manuscripts that were shrunk and curled by the lack of humidity received flattening treatments. The parchments were soaked in a liquid solution, put between two cotton-covered cardboard plates, and pressed in a press. The manuscripts and fragments were then cataloged and photographed using microfilming equipment and single-lens reflex film cameras. The project was announced by Archbishop Damianos in 1981 at the International Congress of Byzantine Studies in Vienna and catalogs were published for each of the grouped languages (Hunger et al., 1982a; Nikolopoulos et al., 1998).

By 1989, the majority of the New Finds collection was microfilmed by the Monastery and the laboratory setup with the assistance of the National Library of Greece. The work of microfilming continued with the Old Collection (manuscripts before the 1975 discovery). This was conducted by the Monastery in the 1980s and 1990s with the assistance of Tasos Christodoulidis. The photographic camera used was a Kodak Recordak Micro-File Machine MRD-2. For capturing images on microfilms, Kodak Recordak AHU Microfilm 5460 (35mm) and Kodak Imagecapture AHU Microfilm 5460 (35mm) cameras were used. The objects were illuminated by four 150-w photoflood lamps.

1.3.11 1982 - Aristotle University of Thessaloniki

In 1981 Ioannis Tarnanidis, professor of History and Slavic Studies in the Aristotle University of Thessaloniki, was invited to describe the Slavonic manuscripts of the New Finds. In June 1982 and subsequent visits to the Sinai (March 1983 and March 1984), Tarnanidis extensively photographed the Slavonic New Finds collection, which he subsequently published as catalogue in 1988 (Tarnanidis, 1988). This catalogue was a milestone for the history of Slavonic language in Sinai, receiving positive reviews and becoming a tool for scholarly research studies. In 1992, Tarnanidis collaborated with František V. Mareš (Vienna) to produce an edition of the “Missale” (a liturgical collection of texts in Sinai Slavonic NF 5). To this end, they visited the Monastery once again, but this time with color films to photograph the specific

incomplete manuscript. The edition never came to be because of the unfortunate death of František, but the work was carried on by Heinz Miklas a decade later (Chapter 1.3.17)

1.3.12 1982 - Freie Universität Berlin

In May of 1982, Dieter Harlfinger, professor at the Freie Universität Berlin, undertook an expedition to the Sinai to study and photograph some selected manuscripts from the newly discovered “New Finds,” as well as manuscripts from the “Old Collection.” In this three-week research visit to the Monastery, he was accompanied by Diether Reinsch, Christian Brockmann and Joseph Sonderkamp. Harlfinger visited the Monastery again in May of 1983 and subsequently published a single volume containing detailed descriptions of 34 manuscripts dating from 861/62 to 1186, and 157 photographs (Epp, 1986, pp. 361–362).

Photography for the project was performed by Reinsch and Brockmann using a Canon F1 camera with Canon Macro FD 50mm lens. The scholars used Afgapan 25 ASA film under natural sunlight to illuminate the object. It was noted by the participants of the project that they had to hold down pages of the manuscripts with their fingers to stabilize the surface to be photographed (Harlfinger et al., 1983, p. 9).

1.3.13 1985 - Princeton Theological Seminary

After eight years of negotiations, James H. Charlesworth, a professor of New Testament literature and language at Princeton Theological Seminary, received permission to rephotograph Sinai Syriac 30. Charlesworth, inspired by the work of the Scottish Smith sisters, wanted to apply new imaging techniques on the ancient manuscript. The photography task was undertaken by Bruce Zuckerman a linguist-photographer of the University of Southern California, and his brother Ken.

The Zuckerman brothers utilized film cameras with various combinations of lights and filters with films of different light sensitivity. They discovered that a combination of ultraviolet light and a yellow filter produced the most useful results on the erased text. As they understood at the time, the ultraviolet light stimulated the molecules of the carbon-based ink in the parchment manuscript (Dart, 1985). An unfortunate term of

events stained the photographic efforts, when copyright issues of the captured images came to surface between Charlesworth (the initiator of the project) and the Zuckermans (photographers hired for the imaging of the manuscript).

1.3.14 1990-2004 - Korneli Kekelidze Institute of Manuscripts of the Georgian Academy of Sciences and Universität Frankfurt

In 1981, Mother Philothei, a member of a convent for nuns in the Sinai, announced the presence of Armenian texts among the New Finds. Following the announcement in 1984, Ilia II, Orthodox Patriarch of All Georgia, visited Sinai and inquired about the Armenian manuscripts. Instead of Armenian, the Patriarch found that the manuscripts were in fact written in Georgian. After returning to Georgia, he contacted the Manuscripts Institute in Tbilisi and relayed the information. In 1988, Zaza Aleksidze was appointed director of the Manuscripts Institute and began planning visits to the Sinai, a difficult task amid the collapse of the USSR. Eventually five expeditions took place, in 1990, 1994, 1996, 2000 and 2004, resulting in the publication of a trilingual (Georgian, Greek, and English) catalog of the Georgian New Find manuscripts, as well as the resurrection of a lost language (Aleksidze et al., 2005).

During his first visit in 1990, Aleksidze described 130 Georgian manuscripts with the assistance of his Deputy Director Mikhail Kavtaria. They were fascinated in particular by several Georgian palimpsested texts, which were studied in the 2000 expedition and recognized as remnants of a lost and forgotten language: “Caucasian Albanian” (Sinai Georgian NF 13 and Sinai Georgian NF 55). In the second trip to Sinai in 1994, Aleksidze was accompanied by scholar Lily Kheviriani (or Lili Xevsuriani) and specialist restorers Lia Kutateladze, Nana Targamadze Darejan Gogashvili, and Irakli Iakobashvili, who assisted in photography of Georgian New Finds manuscripts with infrared sensitive film and microfilms. The team described 140 manuscripts and again found strange, erased characters that intrigued them. In 1996, returning to the Monastery with two conservators and four scholars, Aleksidze studied these palimpsested manuscripts under an ultraviolet (UV) lamp and was convinced of the presence of Caucasian Albanian characters. Not aware of the dangers of UV radiation to the human retina, Aleksidze later realized that extensive damage was done to his left eye from the prolonged use of UV lamps.

A significant breakthrough came with his fourth expedition in 2000 when, with the use of ultraviolet light, Aleksidze was able to photograph the erased texts and further recognize the Caucasian Albanian characters. Photographer David Tshkadadze, along with his son Nikolas (Tato), captured images of all 300 pages of the Georgian / Albanian palimpsests using ultraviolet light. Development of the film was done under difficult circumstances in Tbilisi because of the many electricity blackouts and low temperatures in the work environment that hindered the development of sensitive film, again consequences of the collapsing USSR and the loss of assistance to the Georgian SSR (Aleksidze & Blair, 2003, pp. 38–41).

The final trip by Aleksidze in 2004 was a direct outcome of the breakthroughs made with the erased texts and was devoted to multispectral imaging of the palimpsests. The 2004 expedition was funded by the Volkswagen Foundation, with participating scholars Jost Gippert, professor at the Goethe Universität Frankfurt, and Jean-Pierre Mahé, member of the Institut de France (Académie des inscriptions et belles-lettres). A “MuSIS” multispectral camera was utilized to capture multiple pictures in different wavelengths in the spectrum of 365nm to 1550nm. The imaging system used included a 1/2-inch square Progressive Scan CCD sensor of 1280 × 960 pixels (1.3 megapixels). The application of such technology was an important step for the readability and transcription of larger parts of the erased text (Gippert, 2007, p. 169).

1.3.15 1997 - Sinai Monastery’s Own Digitization Program

To meet the increasing requests of scholars, the Monastery began its own digital photography program in 1997. By that time, it was understood that digital cameras were beginning to be of sufficient resolution to rival film photography. Father Justin, Librarian of Saint Catherine’s, began digitization with a Sinar digital back mounted onto a Canon camera. When Sinar made its own digital camera, it replaced the original Canon camera.

A single workstation made by Alan Buchanan, a conservator from the United Kingdom, was used to hold the manuscripts for digital photography. This book cradle included a system of platens and a rotating spine support, so that the manuscript would be supported through the photographic process. Some years later, the book cradle was upgraded to a workstation made by John Stokes (who had taken a license to use the

technology for the support of manuscripts pioneered by Alan Buchanan). Stokes also developed his own digital camera and software to adjust the camera for different sizes of manuscripts (IWS), and also used calibrated LED light sources for the efficient capture of images. This equipment allowed the Monastery to meet the requests of individual scholars for photographs that would allow them to study the manuscripts at high resolution. But it was soon understood that a single photographer simply did not have the time to build an ambitious digital edition of the whole Library.

1.3.16 2001 - Saint Catherine Foundation Conservation Assessment

From 2001 to 2006, a conservation assessment project took place in the Library of the Sinai Monastery under the direction of Nicholas Pickwood, professor at the Camberwell College of Art. The project's goal was to survey the condition of manuscripts to provide and analyze data for a conservation management project, funded by the Saint Catherine's Foundation. The project was based on a report from a 1998 visit of Pickwood, who suggested a conservation and archaeological approach to the preservation of the Library.

Four to six conservators visited the Sinai for one month at the time, for up to five trips per year. At the end of the project, 3307 bound manuscripts were reviewed by 35 people from nine different countries. Each object was recorded in detail in a ten-page form, and an average of eight photographs were captured for each manuscript (Pickwood & Velios, 2006, pp. 293–297).

The photographic records focused on the condition assessment of the object, and decorative characteristics. This included all sides of the bound objects (inside and outside boards, spine and fore-edge, head and tail), key details of the binding structure (clasp straps, metalwork, endbands, board attachment system, etc.), decorative miniatures and illuminations, as well as areas with significant damage (mold, insects, etc.). The images were captured with a Nikon FM2 camera on Kodachrome 64 color slide film, using an AF Micro Nikkor 60mm lens, fixed on a Uni-Loc Major tripod with a tilt head, and illuminated by two Bouwens Esprit 1000 flashlights. Photographs were then developed in London, and later digitized. In some cases, horizontal raking light was used to capture the surface details of pigments and substrate. The books were

photographed vertically with the assistance of marble blocks to hold them in position (Pickwood, 2004, pp. 33–61).

1.3.17 2007 - University of Vienna

In autumn of 2007, Heinz Miklas, professor of Slavic philology and Balkan studies at the University of Vienna, acquired specialized equipment to digitize erased texts of specific manuscripts with the support and funding of the Austrian Science Fund (FWF). The aim of the project was to image parts of the Glagolitic (ancient Slavic) collection, mainly from the New Finds collection, using both multispectral and normal digital imaging. The project also utilized x-ray fluorescence measuring devices to analyze the inks, parchment, and pigments of as many Slavic manuscripts located in the Sinai Library as possible within the range of funds (Chapter 2.2) (Lettner et al., 2007).

Miklas' involvement with the project dated back to 1995, when classical philologist and Slavist Radoslav Katičić entrusted him with the continuation of the work performed by the Balkan Commission of the Austrian Academy of Sciences. Under the auspices of the Balkan Commission, František V. Mareš, a Slavist from the Austrian Academy in Vienna, had traveled to the Sinai in 1992 and imaged parts of the Slavic New Finds manuscripts. These images, now handed to Miklas, proved difficult to decipher. While the image quality was good, the textual material was obscured. For example, the text of Sinai Slavonic NF 5 often appeared as remains of white powder, due to a chemical reaction of the ink. This suggested that imaging and deciphering of the sources required co-operation of scholars and scientists (Miklas, 2007, 2008, pp. 48–59; Miklas et al., 2008, pp. 13–36).

The results of the project of Heinz Miklas provided new information about the history of the Monastery and the people in it. Miklas found proof for his hypothesis that Slavic pilgrims traveling to the Sinai as religious travelers did not simply visit briefly but must have stayed there for prolonged periods of time, thus making the Monastery a shelter of Old Slavonic writing.

1.3.18 2011 - Sinai Palimpsests Project (SPP)

In 2009, a team from the Early Manuscripts Electronic Library (EMEL) engaged into an eight-year voyage with the Library of Saint Catherine's and the University of California in Los Angeles into the exploration of the Monastery's Palimpsests collection. This collaborative activity perhaps better described as an "adventure," brought together more than 60 scholars, scientists, and technicians from around the world, and revealed over 300 erased texts (undertexts) below texts of the Old and New Finds collections. Chapter 2 of this thesis is dedicated to the Sinai Palimpsests Project by laying out and explaining the work procedures, technologies, and results of the project.

1.3.19 2018 - Sinai Library Digitization Project (SLDP)

Following the success of the Sinai Palimpsests Project, Saint Catherine's Monastery invited the Early Manuscripts Electronic Library (EMEL) to design and propose a project for digitizing the entire manuscripts collection. Following two years of preparation, onsite work started in March 2018. As in the historical expeditions of the 19th and 20th century, the project had to transfer photographic equipment through the desert, resolve challenges that derive from the remoteness of the location, and deal with the volume and fragility of the collection. The University of California in Los Angeles (UCLA) once more provided the services of data hosting and archival storage on behalf of Saint Catherine's, securing that derivatives of this work will be stored in more than one geographical location. Chapter 3 of this thesis dives into the Sinai Library Digitization Project (SLDP), reviewing the workflow and problem-solving techniques of a large-scale digitization project in a historical and remote site.

1.4 Figures of Chapter 1

Figure 1.1

Sinai Peninsula map

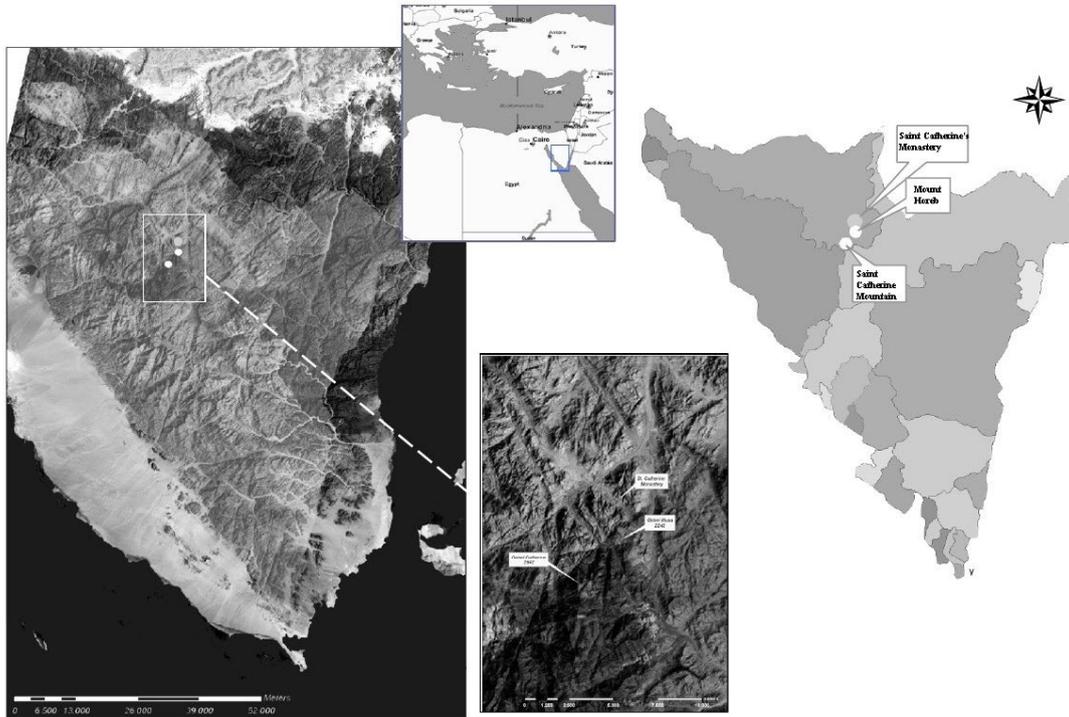
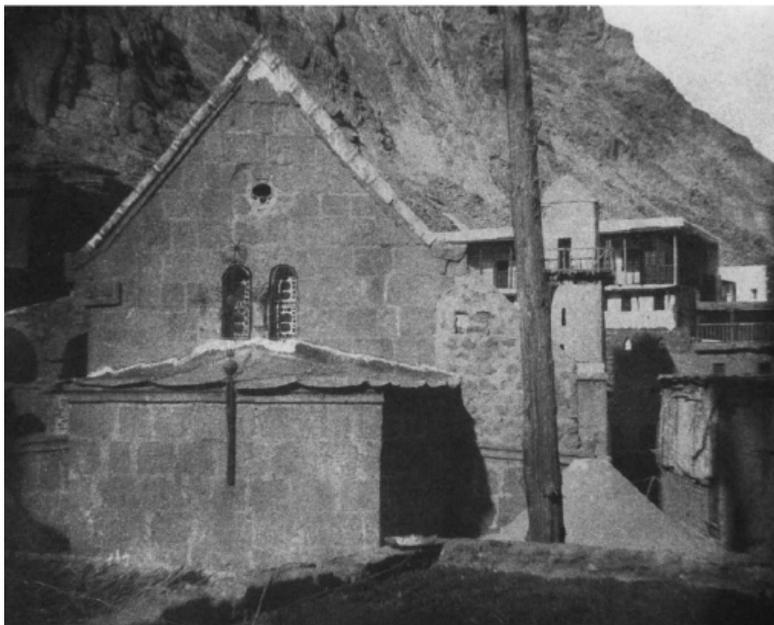


Figure 1.2

Basilica of Saint Catherine's Monastery from 1852



Note. Photograph from Leawit Hunt and Nathan F. Baker. Salt print from calotype negative, 1852. Now in the George Eastman House, International Museum of

Photography, Rochester, New York. Possibly the first photograph ever captured at the Sinai Monastery.

Figure 1.3

Saint Catherine's Monastery in the Sinai in the early 20th century



Note. Glass plate G0892 from the collection of glass plates at Saint Catherine's Monastery. The Monastery before the construction of the 1942 concrete building housing the modern Library

Figure 1.4

Library before renovation



Note. Printed photograph from Saint Catherine's Monastery archive

Figure 1.5

Renovation of Library



Note. Photograph by Librarian Father Justin Sinaites

Figure 1.6

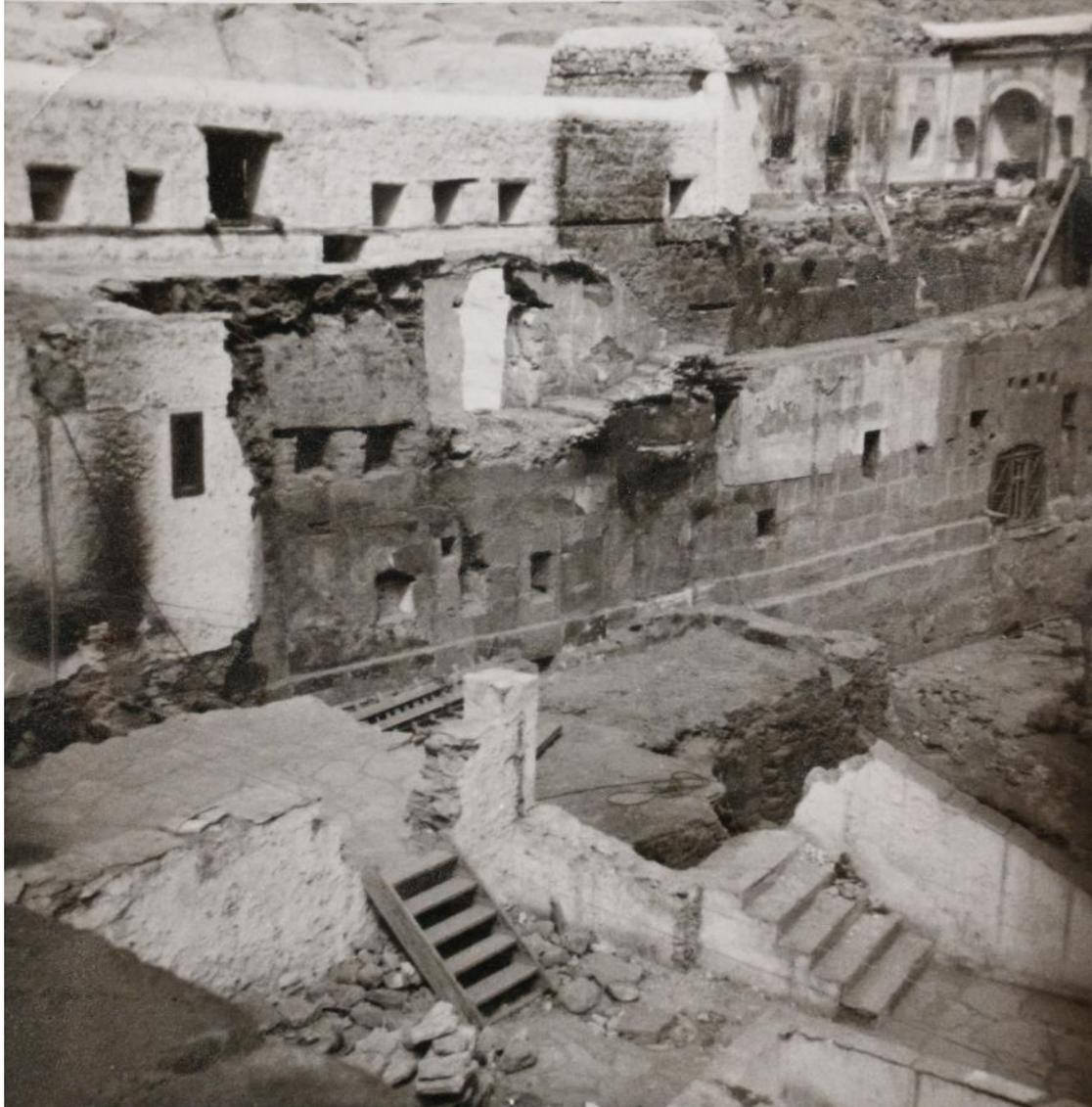
Library after renovation



Note. Photograph by Librarian Father Justin Sinaites

Figure 1.7

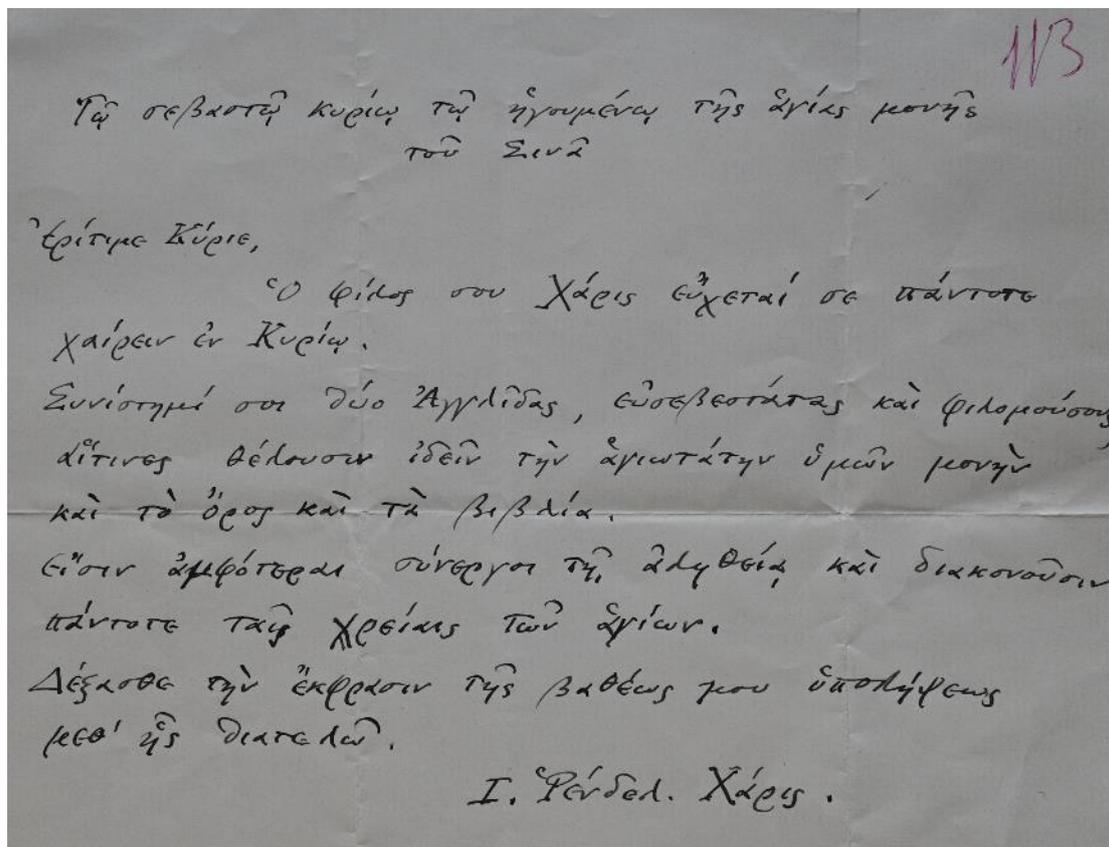
Damages of the Monastery's northern wall after the fire in the early 1970s



Note. Printed photograph from Saint Catherine's Monastery archive. Chapel of Saint George (on the right) and crypt of the New Finds (below)

Figure 1.8

Letter of Rendel Harris to Abbot of Saint Catherine's Monastery



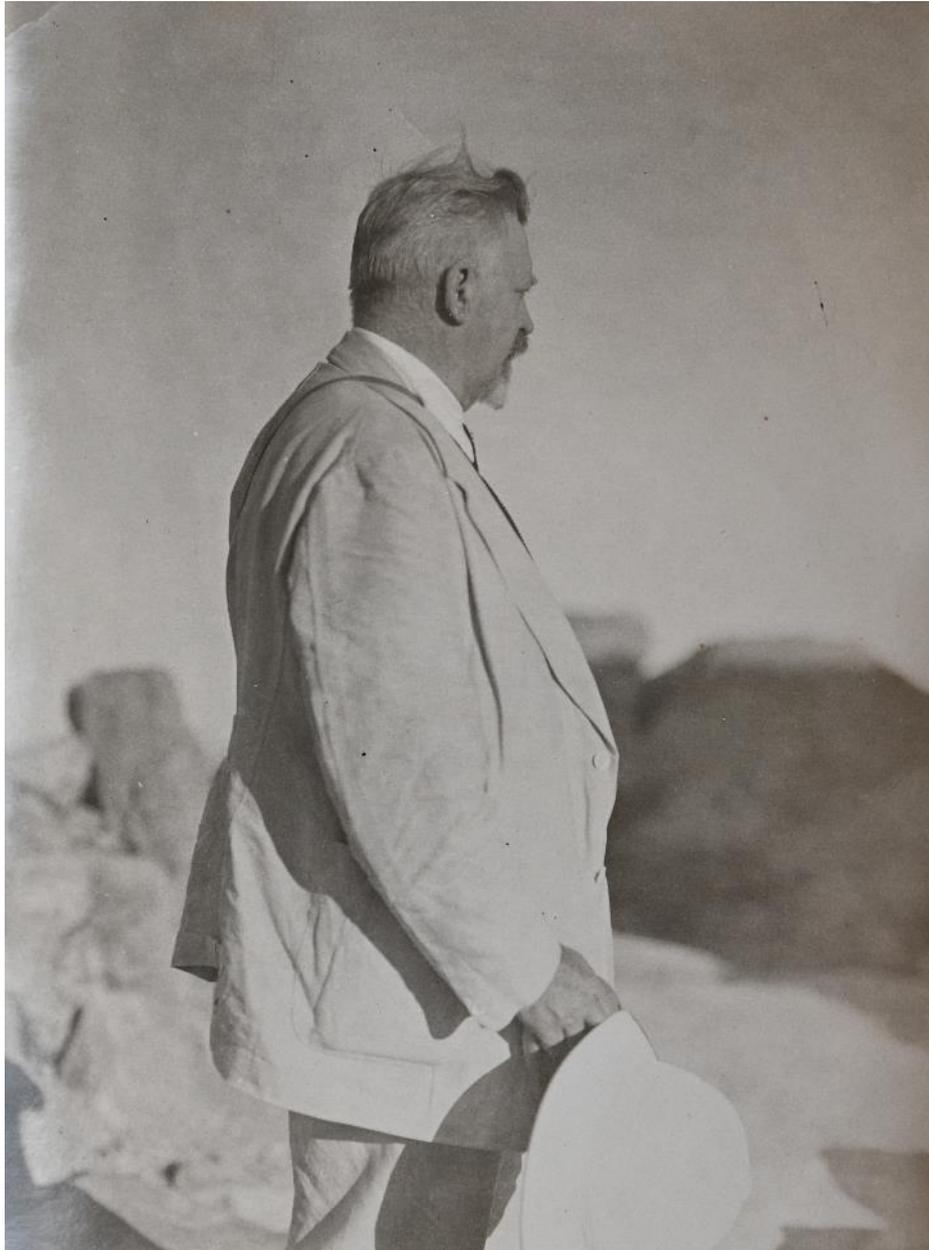
Τῷ σεβαστῷ κυρίῳ τῷ ἡγουμένῳ τῆς ἁγίας μονῆς
τοῦ Σινῶ

Ἐπίτιμῳ Κύριε,
Ὁ φίλος σου Χάρις εὐχεται σε πάντοτε
χαίρειν ἐν Κυρίῳ.
Συνίστημί σοι δύο Ἀγγλίδας, εὐσεβεστάτας καὶ φιλομούσους
λίτινας θέλουσιν ἰδεῖν τὴν ἀριωτάτην ὑμῶν μονὴν
καὶ τὰ ὄρη καὶ τὰ βιβλία.
Εἴσιν ἀμφοτέρωθεν συνεργοὶ τῆ ἀληθείας καὶ διακονοῦσιν
πάντοτε ταῖς χρείαις τῶν ἁγίων.
Δέξασθε τὴν ἐκφρασὴν τῆς βαθεύς μου ὑπολήψεως
μεθ' ἧς διατελεῶ.
I. Rendel. Χάρις.

Note. Letter 113 from Saint Catherine's Monastery archive. Rendel Harris introduces two female scholars from England, most likely referring to Agnes Smith Lewis and Margaret Dunlop Gibson

Figure 1.9

Arthur Hjelt on top of the Sinai mountain



Note. Printed photograph from Saint Catherine's Monastery archive. Handwritten note on the back of the picture from Arthur Hjelt to Porphyrios III indicates the date 23:8:1928

Figure 1.10

Kenneth Clark with Sinai monk and microfilming equipment



Figure 1.11

Kurt Weitzmann with Skevofilax monk Germanos describing icon



Note. Printed photograph from Saint Catherine's Monastery archive.

Figure 1.12

Israeli scholars photographing firman in Sinai Monastery



Note. Sinai Monastery northwest corner of 6th century wall. From the collection of the National Library of Israel, courtesy of: אוסף מיתר

Figure 1.13

Archbishop of Sinai Damianos inside the New Finds crypt 1975



Note. Printed photograph from Saint Catherine's Monastery archive

Figure 1.14

Panagiotis Nikolopoulos with monk inside New Finds crypt



Note. Printed photograph from Saint Catherine's Monastery archive. Panagiotis Nikolopoulos, Director of the Manuscripts Department of the National Library of Greece

Figure 1.15

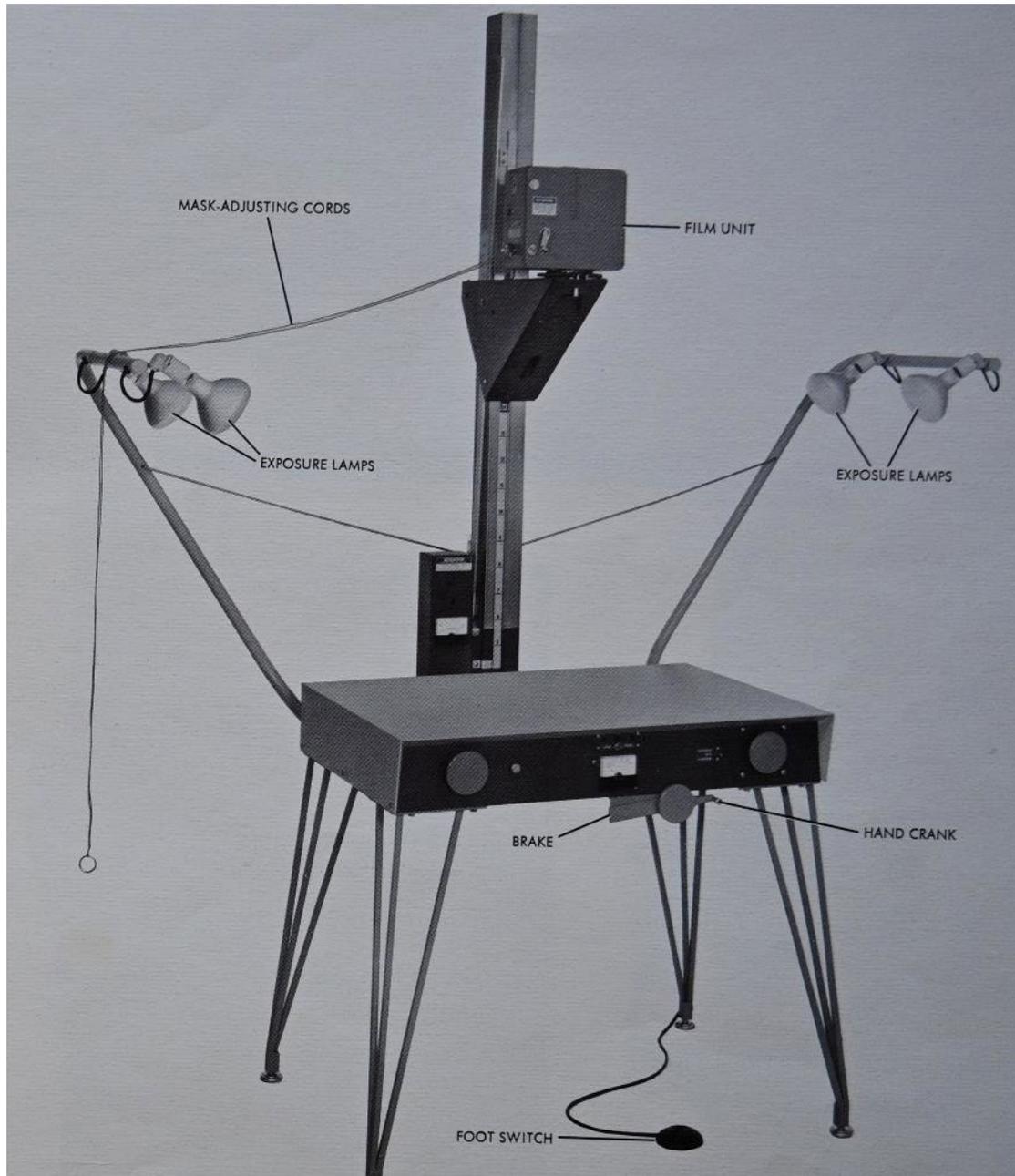
New Finds collection after the work of the National Library of Greece



Note. Printed photograph from Saint Catherine's Monastery archive.

Figure 1.16

Microfilming equipment of the Sinai Library Recordak Micro-File MRD-2



Note. Printed manual from Saint Catherine's Monastery archive.

Part Two Modern Digitization Projects

2. Sinai Palimpsests Project

The Sinai Palimpsests Project (SPP) had three main goals:

- (1) To render erased layers of text as legible as possible using spectral imaging techniques.
- (2) To create initial identification records and describe paleographically the erased text.
- (3) To publish online the processed images in a searchable catalog.

On the basis of earlier work (Chapter 2.2) and especially the Archimedes Palimpsest project, it became clear that the imaging technology had to be refined for this task (Netz et al., 2011). The very complex Sinai collection of manuscripts at Saint Catherine's Monastery includes several palimpsests in many languages and scripts, including Greek, Georgian, Syriac, Arabic, Armenian, Latin, Ethiopic, as well as Caucasian Albanian and Christian Palestinian Aramaic. At the beginning of the project, 110 palimpsests were known in the collection, which is an extraordinarily large number. In comparison, the Austrian National Library of Vienna has 24 palimpsests, and the Biblioteca Laurenziana in Florence has 31 (Magrini, 2008, pp. 163–169; Grusková, 2010, p. 22). By the end of the Project the team had discovered 58 additional palimpsests, increasing the total to 168. The remote location of Saint Catherine's Monastery prevented pillaging and destruction through warfare. Environmental factors, such as the low humidity of the desert, helped to preserve this vast collection. The intense intellectual/spiritual activity of the monks over the centuries explains the attraction of the Monastery for visitors from around the world. The harsh Sinai environment, in which raw materials – sheep or goat skins – for creating new manuscript codices were very difficult to find could potentially explain the importance of recycling used skins, although it must be remembered that a great number of the manuscripts currently preserved at the Monastery were not copied *in situ*. The collection of palimpsests, as known at the point of this writing, consists of entire codices as well as of individual quires, bifolia, folia and fragments of any size.

Here the interest is in the accessibility of these sources through complex technological and digital processing. The first step was to improve the efficiency of spectral imaging at a collection level, to be able to image a large number of objects quickly, since the techniques elaborated before the SPP were used mainly on small number of objects or

“celebrity manuscripts”. The second step was to enrich the available tools for imaging, processing and cataloging palimpsests, or to create new tools by encounters with new challenges. The third task was to develop a protocol (database) to record each step of the process so that not only mistakes could be avoided by future imaging projects, but also so that all steps can be retraced.

Scholarly and technological results of the project were presented in May 2018 in Vienna (Austria), during the international conference “New Light on Old Manuscripts, Recent Advances in Palimpsest Studies” (Rapp et al., Forthcoming).

2.1 What is a Palimpsest?

Palimpsests are manuscripts copied over an earlier, but subsequently erased, original script. The goal is to recycle the scarce and expensive writing material. The word “palimpsest” derives from the ancient Greek παλίμψηστον < πάλιν + ψάω, “again” + “scrape.” Palimpsested manuscripts are mainly made of parchment. There are two major factors explaining why parchment is the writing material which most commonly undergoes the palimpsestation process. First, the word πάλιν (“again”) describes the *second* scraping of the raw material (parchment) in the creation of a new manuscript. It is the second scraping because a first such action was performed in the original process of preparing the animal skin/leather to be used as writing material. The first scraping was done with a sharp knife to remove all hair from the skin and smooth out its two surfaces. During the second scraping, the “*palimpsestation*”, traces of the first writing would be removed. A further aspect of palimpsestation is the reuse of the original writing material, sometimes in different size. Because of their fragility, paper or papyri could not generally survive intact from such a process (Netz et al., 2011, pp. 81–92).

There can be many reasons behind the palimpsestation of a specific manuscript and most often scholars do not have clear explanations. A codex that was used daily over centuries may have been affected by everyday handling with the result that the ink faded and became nearly illegible. Such a codex could be recycled into a new functional manuscript. There are examples in the Sinai collection, where the same text was written above the older, illegible, text. Another reason was that certain texts were considered outdated, but new parchment was very expensive and accessible only to high social and

wealthy classes. When scribes accepted orders or sponsorships to create a new, especially a large manuscript, this meant high cost and precluded acquisition of expensive raw materials. The recycling of parchment manuscripts reduced cost drastically.

The first step in the process of recycling was the disassembly of the old codex following the reverse steps of binding it. The outer front and back covers had to be removed, the spine dismembered, and the individual quires disassembled (number of n folia folded in half and bound together). What was left were separate sheets of parchment that, when folded, could be used for assembling a new codex. However, the ink of the original sheets still had to be removed by scraping with a sharp knife or even washing with water or application of chemicals. In some cases, both scraping and washing was performed: scraping the writing and cleaning the parchment with water. Only then did the new scribe have clean parchment surfaces at his disposal to create a new manuscript codex. In many cases, the new scribe chose to cut the old sheets of parchment into smaller sizes, turn the sheets 90 or 180 degrees from the direction of the old writing, or leave the sheets of parchment intact and re-write on the already existing straight lines of the old text. In the case of the Saint Catherine's Library, numerous examples of palimpsests exhibit a wide range of possibilities for palimpsestation. Manuscripts underwent this process at different times through the centuries, in different languages, in different scripts, and the rewriting may even have occurred in different places. Historical data often describe when a codex could not have been written at the site of the Monastery and therefore the already palimpsested manuscript must have been given as a donation to the Monastery. Other codices most likely underwent the process inside the Monastery, probably because the monks needed a specific ecclesiastical text for the liturgical life. It should be added that not necessarily all folia of a manuscript are palimpsested and that parchments from diverse sources often were combined in a palimpsest.

2.2 Approaches to Sinai Palimpsests Before the 21st Century

Saint Catherine's collection of palimpsests has attracted the interest of many scholars since the 19th century. In 1892, two Scottish researchers – the twin sisters Agnes Smith Lewis and Margaret Dunlop Gibson – recognized a layer of erased

writing in the manuscript Sinai Syriac 30 (Soskice, 2010). Close investigation revealed the undertext to be the oldest copy of the Christian Gospels in Syriac translation (late 5th or early 6th century) (Bensly et al., 1894; Lewis, 1910). In order to read the undertext, Lewis and Gibson applied a chemical substance – ammonia – to the surface of parchment folia (Agnes Smith Lewis, 1898, pp. 92–93 and 122–123). With the help of natural sun light, this treatment enhanced the contrast of the erased text to the point of legibility. While making the older writing temporarily legible in some parts, this chemical interaction left lasting destructive marks on the parchment.

A further step by Arthur Hjelt and his pioneering work in 1928 focused on photography of Sinai Syriac 30 on glass plates coated with special filters sensitive in the ultraviolet spectrum of light, commonly called “Wood’s glass optical filter”. Hjelt efforts were partially hindered by the lack of electricity in the Monastery. Since he could not use special ultraviolet lamps he had prepared for the illumination of the manuscript, the manuscript was exposed again under the light of the sun as a source for ultraviolet light. Hjelt published a facsimile version of Sinai Syriac 30 in 1930 (Hjelt, 1929).

Both of these processes to enhance the readability of the erased text, using chemical substances and exposure to the broad spectrum of sunlight radiation, are invasive and destructive from a modern conservator’s point of view because the object is altered by the capturing processes. Chemical substances left permanent alterations, and exposure to the natural sunlight for unrecorded lengths of time affected the ink and parchment. In more detail: exposing an object to the wide spectrum of radiation of the sun excites electrons in the atoms which constitute the object and thereby produces heat on the surface of object.

A later project by James H. Charlesworth, professor of New Testament language and literature at Princeton Theological Seminary, requested permission to reimage Sinai Syriac 30 with the goal to better decipher its erased writing. After years of negotiations, he was granted permission in 1985, and linguist-photographer Bruce Zuckerman of the University of Southern California and his brother, Ken Zuckerman, undertook the imaging task using various combinations of emulsions, lighting, and filters (Dart, 1985).

In 1994 Zaza Aleksidze, director of the Korneli Kekelidze Institute of Manuscripts of the Georgian Academy in Tbilisi was intrigued by some palimpsests of the New Finds

Georgian collection. In his attempts to read the erased texts better he used ultraviolet lamps with no protective eye-gear in order to transcribe them. As a consequence he was diagnosed with permanent damage on his left eye. Jost Gippert of the Goethe University in Frankfurt joined Aleksidze in 2004 and photographed the Georgian New Finds palimpsested manuscripts with the use of a multispectral imaging system called “MuSIS”. The resulting images assisted tremendously in the further recognition of the erased texts but had the drawback of very low spatial resolution of just two megapixels (Gippert et al., 2008).

In the beginning of the 21st century (2007), a team from the University of Vienna, the Vienna Academy of Fine Arts, and the Vienna University of Technology led by Heinz Miklas studied parts of the palimpsest collection, specifically the Slavonic scripts. The team included material chemists, computer scientists, image processing specialists, and philologists. . They captured multispectral images of approximately 150 folia using an acquisition technique that was inspired by the Archimedes Palimpsest imaging project. Images were captured with two different imaging systems: a Nikon D2Xs RGB camera that captured visual color images for visualization purposes and a Hamamatsu C9300-124 monochrome camera with a spectral sensitivity from UV to NIR (330nm-1000nm). Although this approach followed modern standards of non-invasive techniques for the study of the object, it faced difficulties concerning the registration of images from the two modalities (Gau et al., 2011).

Based on the findings from these earlier projects, the SPP team decided to adopt and develop non-destructive and non-invasive capturing method as a requirement for a large-scale analysis of the palimpsests collection through digital means. Furthermore, from the lessons learned from the past, the SPP adopted safety measures for its photography personnel, acquired high spatial resolution digital imaging sensors for better clarity of the pictures, as well as quartz made lenses for the absolute registration of the multispectral photographs.

2.3 The Sinai Palimpsests Project (2009-2017)

Two years before the initial planning of the Sinai Palimpsests Project (SPP), in 2007, the Librarian of Saint Catherine’s Monastery Father Justin Sinaites witnessed the spectral imaging of the “Archimedes Palimpsest”, a 13th-century prayer book written

over several earlier texts, including two treatises of Archimedes which were unknown until the acquisition of the manuscript by the Walters Art Museum in Baltimore in 1998 (Netz et al., 2011). Image scientists further developed the integration of remote sensing methods for image capture of historical documents in order to make the undertext readable again.¹² The Sinai Palimpsests Project of the Early Manuscripts Electronic Library (EMEL), which aimed at imaging a large number of palimpsested manuscripts, started a pilot phase of collecting sample spectral data from in Saint Catherine's Library in 2009. The techniques were based on the technologies of the Archimedes Palimpsest project. In the following years, image processing techniques and illumination systems were refined, leading to the start of the Sinai Palimpsest Project in December 2011. The project was funded by a generous grant of \$2.1 million from the Arcadia foundation. The team of imaging scientists, consisting of Roger Easton, Jr. (Rochester Institute of Technology), Keith Knox (formerly at Xerox Corporation) and William Christens-Berry (Equipoise Imaging), with the technical support of Ken Boydston (MegaVision) transferred equipment and installed a spectral imaging system in the Monastery. My role was that of chief camera operator under the direction of Michael Phelps (Project Director) and Claudia Rapp (Scholarly Director), as well as Nikos Zarkantzas and Michael Toth (Project Managers) (Father Justin Sinaites, 2014, pp. 18–20; Rapp & Phelps, 2017, pp. 4–5).

The imaging project was completed six years later in 2017, with more than 200,000 images of 6900 palimpsested folia imaged representing 74 manuscripts. In the process the team expanded the number of 110 palimpsested manuscripts known to the scholarly community by another 58 manuscripts.¹³ Some of these finds came by chance, most resulted from the in-depth research of collaborating scholars, a few by diligent observation of myself as camera operator and researcher. At the time of this writing, 173 palimpsest manuscripts are known to be in Saint Catherine's collection¹⁴.

¹² David Cooper, former Librarian at Corpus Christi College, Oxford University, accompanied Father Justin and contributed to the early discussions of a text recovery project at St. Catherine's Monastery.

¹³ Number provided by Giulia Rossetto who managed the list. Grigory Kessel identified 10 palimpsests during his visits in the Sinai Monastery as part of the SPP.

¹⁴ According to the latest assessment of Rossetto-Kasotakis. This number does not include the over 100 palimpsest fragments discovered and recorded by Kasotakis personal research in the New Finds fragments collection, which is located in the Archive of Saint Catherine's Monastery (March-May 2020). Among the new discoveries recognized as palimpsests are further fragments from Sinai Arabic NF 66, as well as Sinai Syriac NF frg. 61.

After the conclusion of onsite data collection, the twenty-seven participating scholars, located from Tbilisi in the Republic of Georgia to Seattle in the U.S.A., identified some 307 erased texts ranging in date from the 5th to the 12th century and in 11 languages (Greek, Georgian, Arabic, Syriac, Christian Palestinian Aramaic, Armenian, Latin, Slavonic, Caucasian Albanian, Coptic, and Ethiopic). The newly identified and recovered undertexts included many previously unknown texts, the oldest extant copies of several known texts, as well as first attestations of known texts in new languages (e.g.: Christian Palestinian Aramaic translations of Greek texts). The scholars' results have been made available during the SPP's online publication phase in 2017 (UCLA, 2017),¹⁵ through conferences and presentations, as well as articles from broad media sources (Marchant, 2017; Williams, 2017; Gray, 2017).

2.4 Recovering Unreadable and Unknown Texts through Digital Multispectral Imaging

Multispectral imaging can discover and reveal palimpsested texts, show redacted and degraded writing, uncover under-sketches in paintings, and even alterations and forgeries. From the visible bands of multispectral data, color images may be derived that are more accurate than those obtained from conventional RGB photography. Spectral imaging has not yet been widely adopted as a way of image capture, but it is used in the cultural heritage community around the globe. Noteworthy examples include the Magna Carta at the British Library, the original drafts of the Declaration of Independence at the U.S. Library of Congress, the Codex Vercellensis and the Vercelli Mappa Mundi at the Museo del Tesoro del Duomo in Vercelli, Italy, the Dead Sea Scrolls at the Israel Antiquities Authority in Jerusalem, as well as paintings of Picasso, Gauguin, Monet, Delacroix, Da Vinci in various museums and private collections.

Multispectral imaging as technology combines images with high spatial and moderate spectral resolution. Digital images with high spatial resolution may be magnified so

¹⁵ The database is hosted by the University of California Los Angeles (UCLA).

that individual letters may be easier identified. Moderate spectral resolution produces images under several – perhaps 5-25 – different wavelengths of light (Falk et al., 1986).

To put matters simply, multispectral photography is comparable to any kind of photography. The important addition is the taking of multiple images of each folio under different colors of light or other conditions in a highly controlled imaging environment. In the SPP, 33 images were collected of each folio. Since all procedures are sufficiently documented and performed under a controlled environment, the imaging process can be repeated months or years later to analyze and track changes of spectral properties (e.g., reflectance, transmittance, fluorescence, color) and spatial properties (e.g., size, shape, texture). The process uses a high-resolution monochrome image sensor for creating a series of images. For each individual image capture, the object is illuminated with a narrow waveband of a particular light-emitting diode (LED). The wavelengths emitted by individual LEDs cover a range from the ultraviolet region of the spectrum through the visible and into the infrared. Moreover, a number of images are captured through filters that can be preselected, in order to detect and discriminate emissions excited by the illuminants. The series of images captured for a specific folio of the object can then be processed for reproduction, discovery and monitoring.

Compared to the imaging of the “celebrity manuscripts” noted above, as well as other initiatives around the globe, the Sinai Palimpsests Project is the first to focus systematically on one of the largest collections of palimpsests in the world. Methods were developed specifically for documenting the palimpsested manuscripts and the processes of imaging. The technological-digital aspect of the project permitted development of better equipment and processes that will benefit future projects. Thus, the scholarly aspect of the SPP and its technological-digital side were intimately related.¹⁶

¹⁶ Advancement of image processing techniques that led to the development of the open-source tool “Hoku” by Keith Knox (Early Manuscripts Electronic Library, Scientific affiliate); development and advancement of the Infrared Transmissive light source by William Christens-Berry (Equipoise Imaging) and Kenneth Boydston (MegaVision).

2.5 Spectral Imaging System Description

The main components of the spectral imaging system are the light sources, the photographic camera, and the capture-controlling computer. The camera system itself is composed of the digital back that houses the imaging sensor, the lens, a camera body that allows the lens to be mounted on the digital back, a computer-controlled aperture and shutter, and filter wheel. The camera system can be mounted on a book cradle or a copystand, depending on the form of the object to be imaged. (Figure 2.1 and 2.2)

2.5.1 Digital Sensor

The MegaVision E7 monochrome digital camera back houses a 50-megapixel KAF-50100 sensor. This sensor has a dynamic range of 14 bit analog-to-digital converter (ADC) that can produce images with 12 bits of dynamic range for a total of $2^{12} = 4096$ different “brightness” levels. The resulting file is approximately 100 megabytes in size.¹⁷ The sensor is a charge-coupled device (CCD) with 8176×6132 pixels, each with a linear dimension of 6 micrometers. The connectivity between the digital back and the capture computer happens through a GigE network connection.

2.5.2 Lens

MegaVision specifically designed a 120mm f/4.5 Macro UV-IR Apochromat parfocal lens with the spectral range of 350nm – 1000nm. This is an innovative technical camera lens that incorporates both floating elements and advanced UV-VIS-IR apochromatic color correction technology. Six extra low dispersion glass elements and one aspheric element are used to achieve an unprecedented level of performance for multispectral documentation, forensics, scientific imaging, and fine-art photography. After focusing the image in visible light, no refocusing is necessary for either ultraviolet or infrared imaging, thus enabling extremely precise color channel registration in multispectral applications. The excellent color correction is also valuable

¹⁷ Between 2009 and 2012 the MegaVision E6 was used in the SPP. This digital back houses a 39 Megapixel sensor and produces files of approximately 78 Megabytes. The E6 CCD array is 7216×5412 pixels, with a 6.8-micron pixel size. The connectivity between the E6 digital back and the capture computer happens through an IEEE 1394 Firewire 400 connection.

in visible light photography because it completely eliminates artifacts suffered by other lenses in high contrast outdoor scenes (e.g., “purple fringing”). The adjustable floating element, unique among view camera lenses, ensures superb optical correction at all object distances.

The 120mm UV-IR Apochromat lens can be used with either a standard or digital copal-0 shutter. The digital shutter can be controlled with MegaVision’s very compact USB AutoStop controller, providing both electrical power and control over USB from a host computer. The controller provides a sync output, enabling control of cameras and lights with sync trigger inputs.

MegaVision 120mm lens specifications:

Focal length 120 mm

Aperture range f/4.5 to f/45

Waveband 320 to 1100 nm

Maximum aperture circle f/4.5

Minimum aperture circle f/16 100 mm

Length 118 mm

Max. diameter 75 mm

Weight 726 grams

Min. object distance 0.47m

Max. image scale 1:1

Shutter Copal #0

Hyperspectral (corrected for retention of focus from Ultraviolet to Visible and Infrared wavelengths)

2.5.3 Lights

A light source, such as a ring flash attachment, that is perpendicular to the scene on the optical axis will tend to eliminate surface texture caused by shadows and increase flare, especially from specular surfaces. This can be a significant problem for illuminated parchments which also often used gold foil. In such cases, the recommended incident lighting angle is 45°, in combination with diffusion over the 350-1,000 nm range. Two main banks of lights are used for the 45° illumination. Each houses 30 individually controlled LED units that include their own diffusion or amplification lens. Two low-angle lighting sources at 15° were used for “raking” incidence illumination, where light emitted almost parallel to the surface can enhance surface texture or depth variation of a surface. These lighting sources take the form of

linear arrays of visible and IR LED's approximately 50mm × 50mm × 450mm, with six LED's arranged along the long axis. Finally, two different transmissive light sources were designed specifically for the project, one that could be attached to the Stokes Preservation Book Cradle (PBC) and one that could be used with the copystand setup. The transmissive light source utilizes at least 13 LED lights illuminating in four visible and four infrared bands. In the course of the project, the lights sources were upgraded to accommodate bigger power supplies in WATT, in order to increase their performance and illumination output. Two auxiliary lights were also added housing 12 LED at three wavelengths, 366nm, 385nm and 429nm.

The light sources operated the following wavelengths of light (numbers in nanometers -nm-). Color correlation based on: (Bruton, 2021)

(UV)	365	385	400							
(VIS)	420	450	470	505	530	560	595	615	630	655
(IR)	700	735	780	850	940	1050				

2.5.4 Software

To automate the procedure of capturing multiple exposures of the same object, a loadable file, the “N-shot table” is used. The n-shot table is a feature of the MegaVision capturing software “PhotoShoot” (*MegaVision Cultural Heritage - EurekaVision*, 2021). From the n-shot table, the operator can create a capturing sequence of multiple shots. In an imaging sequence the following imaging attributes can be individually configured for each shot: aperture setting, exposure time, each one or any number of connected illuminating devices, any combination of LEDs of the selected illuminating devices, as well as any combination of filters for up to two imaging filter wheels that are connected to the imaging setup.

The capturing software communicates and controls the illumination devices (LED lights), filter wheels, shutter and aperture through a USB control box. All devices are linked to a USB hub enclosed in a box that in turn is connected to the capture computer. With all devices connected and calibrated the spectral imaging system is complete and ready for image capture.

2.6 Workflow

The workflow of the Sinai Palimpsests Project was divided into five phases:

1. Initial identification and cataloging.
2. Spectral acquisition of data (photography).
3. Image processing.
4. Scholarly identification of the palimpsest text.
5. Online publication.

In the Sinai Palimpsests Project these steps were adapted to the complexity, variety, and large size of the collection, as well as to the five-year funding schedule.

The identification of a palimpsest codex is done by carefully examining each page of the manuscript. Tools such as light torches, handheld ultraviolet light torches, or illuminating surfaces in the form of thin leaves that can be inserted between pages, are used in conjunction with experience and a very high degree of empirical observation. Each page of a manuscript is examined and observed illuminated from different angles or even through back illumination. After a single folio or an entire codex is identified as a palimpsest, it must be cataloged.

Cataloging includes the many recorded features that will later be useful in photography, image processing, and further identification of the erased text. A detailed codicological analysis records the physical size of the codex, as well as the size of folia or fragments. The "upper" (newer) writing, and the "lower" (older-erased) writing are described according to their language groups, type of writing (majuscule, minuscule, cursive, etc.), the color of the ink and its readability with the naked eye, as well as the writing angle of the erased text in relation to the new "top" writing (0, 90, 180, 270 degrees relative to the "upper" script). The literary content and dating of "upper" writing. The parchment is identified by flesh or hair on each folio side since flesh and hair sides absorb ink in different ways. Often hair follicles on the outer side can be recognized, as opposed to the inner one which is uniform without any spots. This description is essential in order to reconstruct the sequence of the erased undertext. Often erased text extends across two pages, when for example the original folio was turned 90 degrees and reused as a new bifolio.

The cataloging of these features is hosted in a special database called "KatIkon", which was created by developer Doug Emery specifically for this project under the supervision and guidance of the Early Manuscripts Electronic Library (EMEL). Emery

developed his database on the foundation of his previous work for the Archimedes Palimpsest project at the Walters Art Museum in Baltimore. Katlkon is not just a codicological database, but a tool that can follow the manuscript through its various stages: visual codicological examination, creation of shot lists for image capture, onsite quality control; it also has to record the type of offsite processing, data distribution to scholars, and finally assist in the online publication of processed images by accompanying short descriptions. Katlkon evolved in the course of the five-year project by receiving two major revisions (Emery & Rapp, 2018). Claudia Rapp (University of Vienna) as the scholarly director of the SPP performed the initial cataloguing and identification with the assistance of Giulia Rossetto (University of Vienna).

Each manuscript receives a database identifier which consists of a series of numbers. The individual folia receive this database identifier with a sequence number starting from the beginning of the palimpsest object until the end of it. The manuscript numbers are given based on the order of the initial cataloging. Inside the database entry the shelfmark of the object is also recorded in order to identify the object by existing catalogs. An example is Sinai Georgian 49, which is identified in the database with the call number K0052. Individual folio 2r of Sinai Georgian 49 is identified as K0052_000003, where K0052 is the identifier of the object and 000003 is the third image set captured in the imaging process.

Table 2.1

Example of shot sequences file naming schema

Position	Subject	Pass group	Cube
1	1r	r	K0052_000001
2	1v	v	K0052_000002
3	2r	r	K0052_000003

The manuscript entry incorporates descriptive metadata for the entire object and in addition each individual image set includes descriptive metadata for the specific folio. Using the database, a user can generate a shootlist for a group of folia or an entire object. A shootlist consists of individual text files for each image set or number of folia that

need to be imaged. The text files include all descriptive metadata for the specific folio to be imaged and information about the entire object. This shootlist is handed to the imaging team and guides the subsequent photographic capture. The camera operator is responsible for loading a dedicated text file (.txt) at the beginning of the imaging sequence of a folio with the corresponding information of the folio from the shootlist. The camera operator can identify the text file that needs to be loaded by following the filenames order. Once the text file is loaded into the imaging software, all information is presented including the folio number, which the operator must verify as the next image is to be shot.

Before any imaging takes place, the imaging system must be calibrated and documented. This is done at the beginning of an imaging session and at the start of each imaging day or a new manuscript object. The calibration procedure varies between the start of a new object or the beginning of a new imaging workday while imaging the same object. The thoroughly documented calibration ensures that each object will be imaged under the best possible conditions for the specific attributes of the manuscript's condition. Manuscripts are evaluated based on the conservation condition: bound or unbound objects; condition of binding where existent; condition of individual folia based on the fragility of the parchment; thinness or thickness of parchment as well as rigidity or stiffness of folia. When handling an object, special care needs to be given even to the condition of the ink. Most of the inks in the Sinai can be quite dry and require to not be scratched against other surfaces. Inks can penetrate the parchment but also remain as a thin layer on top of the parchment surface, this applies for both the "newer" and "erased" inks (depending on the thoroughness of the erasure procedure).

During the SPP two main system setups were used: a copystand and a sophisticated book cradle. The copystand setup is used for unbound objects or manuscript fragments. Among the New Finds collection of Saint Catherine's, the majority of the objects are unbound or fragmentary. This copystand setup positions the camera at a 90-degree angle over the object, held by a vertical column that supports the imaging setup. The lights are positioned right and left at 45-degree angle from the object. The two main lights are positioned in a way that the center of the lights is in the same straight horizontal line of the imaging lens. This gives enough space for the operator to position the objects to be imaged safely.

The second imaging setup is configured around the Stokes Preservation Book Cradle (Stokes PBC). The Stokes PBC is a sophisticated device that consists of a mechanical motorized book cradle and a motorized and computer-controlled camera stand. The camera sensor and object are always parallel to each other in a V-shape formation. The book cradle is designed to rest the manuscript in a position that avoids stressing the object's spine. While the imaging of the object progresses, the computer-controlled cradle can rotate the front and back resting surfaces of the manuscript around the axis of its spine. In this way, the spine can remain in the same position, but the front and back weight of the object can be moved forward or backwards depending on the position of the opening of the book, in order to release strain from the spine. (Figure 2.3)

For each imaging session the lights and camera must be positioned on either the Copystand or Stokes PBC. The correct angle of the lights must be measured so that it corresponds to 45 degrees from the object. This is accomplished by measuring the distance and height of the lights and moving until the desired outcome is achieved. The camera position is also calculated based on the spatial resolution required for the object to achieve the best outcome in clarity and sharpness. The distance of the camera to the object is determined by the latter's size, since each single shot needs to capture the entire object. These camera movements are documented for each individual object and need to be consistent throughout the imaging sequence.

With the camera sensor in place, the lens is focused on a specific focal plane. Sinai manuscripts tend not to be flat. Due to the environmental conditions of low humidity parchment has shrunk from its original size and curled up. This can create wavy curves that present a challenge to focusing. The operator needs to evaluate the imaging aperture and the focal length in order to place the focusing point in a position that can accommodate both the lower and higher parts of such curves of the object. The depth of field (DOF) determines the distance from the farthest to the nearest objects that are in sharp focus in an image. DOF is linked to the aperture value set on the lens of the camera and it increases as the square of the f/number (diameter of opening of the aperture). This is an effect of light traveling through shallower angles as the aperture diameter is reduced and vice versa when its increased.

Once all lights and camera are in position, the sensor sensitivity is set at 100 ISO, which is a low setting that produces the best low “noise” characteristics, an image without misread electronic signal information. Individual light sequences must be selected from the n-shot table or created anew. The n-shot table as described above plays a central role in the planning and execution of the imaging sequence that the operator can configure before the photography. 33 images were captured for each folio during the Sinai Palimpsests Project. This means that 33 shots were configured individually through the n-shot table. All shots must be tested and calibrated for the optimal exposure time based on the wavelength and/or filter combination that is used. Different exposures have to be used for the calibration of the equipment and for the individual manuscripts since different parchments can have different reflectance and fluorescence attributes. Even though a manuscript is usually composed of similar parchment materials, the operator must check for over exposures or underexposures of specific folia or patches of folia inside a manuscript.

To measure accurate exposures in the visible wavelengths, an x-rite color target is photographed. The white and grey patches are measured in L*a*b* color space and each shot is calibrated accordingly in order to avoid over- or underexposure. The order of the shots in the n-shot table is as follows: Main bank, where the two main illumination sources house UV-VIS-IR LEDs. Raking, that uses IR and Blue wavelengths. A filter wheel sequence of UV and VIS lights that is captured through a combination of filters. And finally, transmissive sequence of VIS and IR lights illuminating the object from below. (Figure 2.4 and 2.5)

A flat-field correction is performed to calibrate the imaging system. This technique eliminates the effects of image artifacts caused by distortions in the optical path, and by variations in the sensitivity of the detector; variations may be as small as speckles of dust on top of the imaging sensor – a common problem in the Sinai desert environment. In flat-fielding, a white piece of non-glossy texture-free paper is imaged, which must not contain any chemical whitening reagents that significantly fluoresce under UV illumination. The images need to be slightly defocused to avoid capturing small-scale imperfections of the white paper.

When the calibration of the system is complete, the shootlist is retrieved from the “KatIkon” database and loaded in the form of text files into the capturing software. This

step can be manually performed, but the predefined population of naming and metadata fields ensures the correct application of metadata of the object to the images. Once imported into the capturing software and according to the information of the metadata text files, the software automatically creates the corresponding storage folder using the predefined filename of the object and data set.

The step of spectral imaging is a repetitive process that appears simple but demands the full attention of the camera operator, since it is usual during repetitive processes for deviations to occur that are only noted once they have escalated to greater errors. The beginning of the imaging starts with the proper placement of the object. Special care is given to this step given the fragility of most of the manuscripts in Saint Catherine’s collection. A single folio or fragment needs to remain perfectly still for the duration of the imaging sequence; thus, it needs to be held down with some support.

Parchment adapts slowly to the environmental conditions of its environment, based on the levels of humidity. The storage conditions of manuscripts at Saint Catherine’s are of relatively low humidity (2018-2019 average at 24.57% humidity) with gradual deviations throughout the year.¹⁸ Once the object is inside the imaging room for a prolonged period of time, it will absorb some humidity caused by the presence of the system operators. This change sometimes makes the parchment more flexible.

Table 2.2

Temperature and humidity recorded in the storage room of manuscripts at Saint Catherine’s Library

Date	Low	Average	High	Range
16/03/18-21/05/18 Temp. Celsius	18.5	21.1	24.8	6.4
16/03/18-21/05/18 Humidity	15.3	26.9	35.0	19.6
21/05/18-31/07/18 Temp. Celsius	24.1	27.3	29.5	5.4
21/05/18-31/07/18 Humidity	21.0	26.4	32.2	11.2
31/07/18-10/10/18 Temp. Celsius	26.3	28.1	29.9	3.7
31/07/18-10/10/18 Humidity	15.3	25.5	28.6	13.3

¹⁸ Data recorded between March 2018 and March 2019 from inside the manuscripts’ storeroom by the Monastery’s librarian Father Justin.

10/10/18-03/01/19 Temp. Celsius	11.4	17.3	26.6	15.3
10/10/18-03/01/19 Humidity	24.6	31.0	38.7	14.1
03/01/19-15/03/19 Temp. Celsius	10.6	12.9	15.6	5.0
03/01/19-15/03/19 Humidity	23.9	29.2	38.9	15.0

Another factor is the tension of an object and the resistance it presents when it is taken from its original resting position. Over the 1500-year history, these manuscript objects may have been stored for hundreds of years in the same position, making the parchment of the folia adapted to the tension of the spine that keeps them together. Even if the preservation condition of an object is good, in most cases a bound manuscript will present some initial resistance when it is opened, as the folia and spine change from a resting position to a reading or imaging position at an angle of 70-110 degrees.

Both humidity and tension are factors that are taken into consideration when manuscripts are placed upon one of the two imaging systems. Special care is given to individual folia, since the position for each varies throughout the bound manuscript. This delicate procedure can take up to 45 minutes in an initial setup of the object and up to 6 minutes between folia while imaging the same manuscript. The average initial positioning of an object takes 10-15 minutes including the positioning of the camera distance, and the average change between folia takes 1-2 minutes, including verification of the proper folio number to be imaged. These “technical” details are decisive for the quality, i.e., readability of the images. They, of course, also determine the amount of project funding necessary.

During the image acquisition sequence, the camera operator has to be careful to check that all illuminating sources operate as programmed and turn on and off in the correct order and synchronization. This presents considerable problems in the remote location of the Sinai where electricity is not consistent. Electrical current needs special stabilization and is prone to frequent failures. The micro components of the spectral imaging system, even though they connect to the electrical grid through a power stabilizer and battery, are still sensitive to micro alternations that can lead to errors during the imaging sequence.

While imaging a sequence, the PhotoShoot capturing software was programmed to generate three files for each shot. A raw file in DNG format, a flattened file in TIFF

format that is corrected based on the flat-field correction algorithm, and a JPG file whose file size is small enough for fast image preview for onsite quality control. At the end of each imaging sequence of a folio, the camera operator is prompted to generate a color file by combining seven visible wavelengths. The resulting color file is of high color accuracy (better than may be obtained with a conventional RGB camera) and is white balanced according to the white patch of the x-rite color checker that is included in the shot.

Once the imaging sequence is complete, the camera operator performs an initial quality control by checking color accuracy and luminance based on L*a*b of the X-Rite color target. The number of captured shots is verified. And finally, the registration of all shots is checked in order to ascertain that no movement happened to the object during the time-consuming imaging procedure.

The camera operator runs a command line script that checks the last generated folder on the system and creates MD5 checksums for all the files of the new folder. This MD5 checksum follows the object and can verify data integrity in every copy or movement of the data. Once checksums are created, a local backup is created on a network drive. Next, a second person with the role of quality control operator verifies with a second and more detailed inspection the color accuracy, the final number of captured shots, and any misregistration of the object through the shots. After transferring the data to external transfer hard drives, the quality control operator verifies the MD5 checksum integrity once more.

After quality control and integrity data verification, the hard drives are shipped to imaging scientists for initial processing. Imaging scientist Keith Knox generates different variations of predefined combinations of the data resulting in the first processed images of the data set. This process is semi-automated in the form of scripts that run through batches of data. The processed images are then sent to collaborating scholars based on their expertise on the language of the object. Through a feedback loop scholars and imaging scientists communicate between them and report folia where the automated batch processing did not give optimal results. Images of less than optimal quality are sent out to a second team of imaging scientists who perform a supervised process for each individual folio. Roger Easton, William Christens-Berry, and Dave Kelbe, with the support of students, performed the lengthy task of supervised

processing. The processed data are then sent again to scholars, who in turn report their initial identifications. New data are updated and recorded in the KatIkon database based on the feedback of the scholars.

Finally, spectral raw and processed data are transferred to the University of California Los Angeles. In-depth analyses of the context by the scholars are not yet included in this step. UCLA data archivists designed and built a data portal that was able to present IIIF-compatible data of the visible and processed images of the Sinai Palimpsests for scholarly use (International Image Interoperability Framework as standardized approach of describing and publishing images over the internet). They installed an Opensource Mirador viewer which they edited to fit the needs and criteria of presenting spectral data as layered images online. The TIFF images were converted into JPG2000 for online publication and fragmented for data protection according to magnification level.

2.7 Digital Spectral Data Processing

The collection of multispectral images is only the first step towards recovering erased texts. Through the imaging of an object under different wavelengths of light, the camera operators attempt to record the differences in the reflectance or fluorescence of different inks as well as the parchment. When such differences are easily visible between some wavelengths, then the text is more easily recoverable. Contrary to that scenario, some differences will only appear in very low-contrast variations spread across many different wavelengths. To recover such difficult cases, sophisticated algorithmic methods are applied to extract the low-contrast differences. This process is called image processing (Baxes, 1994).

The, in retrospect, simple methods developed for image processing during the Archimedes Palimpsest project utilized visible differences captured in images between visible and infrared wavelengths. For the Sinai Palimpsest Project, these techniques were refined and their systematic use in a large-scale data processing developed by the four main imaging scientists mentioned above as well as by students and collaborators of the project including the author of this dissertation.

Ultimately, image processing seeks to present in a computerized and objective way the differences between background (parchment), obstructing feature (newer overwriting), and feature of interest (erased or damaged text). The different captured wavelengths permit to enhance the features of interest. One combination is the placement of different bands in the channels of a three-channel red-green-blue image (RGB), which creates a new pseudocolor rendering of the image. For example, channels can be switched in the following way:

Table 2.3

Example of alternation between images in channels of an RGB image

RGB Channels	RGB image	Pseudocolor image
Red channel	Red	Ultraviolet
Green channel	Green	Red
Blue channel	Blue	Blue

A second combination can be made by simple application of arithmetic operations (sums or differences) among two or more images. By calculating the arithmetic sum of two images, invariant features are enhanced relative to those that change from image to image. On the other hand, by calculating the arithmetic difference of two images, features that are constant are attenuated, whereas features that vary are enhanced.

2.7.1 Batch processing

The two techniques mentioned above constitute the automated and batch approach of the SPP data set which resulted in approximately 70% of the generated legible images. Specific scripts were written in Unix language by Keith Knox and applied rapidly over large amounts of data in a predefined approach (Netz et al., 2011, p. 207).

These scripts can take advantage of the known reflective properties of iron gall ink, which was widely used in the undertexts of the Sinai manuscripts or other inks that have similar properties. Short wavelength illumination (ultraviolet and blue) makes iron gall ink appear in greater contrast, whereas longer wavelengths (red and infrared) make it

less visible, to the degree of making it disappear at 1200nm. During the image capturing process, the object is illuminated from shorter to longer wavelengths, both the undertext and the overtext tend to be less visible towards the longer wavelengths, but the fainter undertext disappears first. Utilizing the arithmetic approach mentioned above, the automated algorithms combine shorter wavelengths of ultraviolet or blue images (where both the undertext and the overtext appear) with longer wavelengths of red or infrared images (where only the overtext appears), resulting in the differentiation of the undertext from the overtext. In total, 25 combinations were applied for each palimpsested page. (Figure 2.6)

Another processing technique took advantage of a phenomenon that occurs in the interaction of ink and parchment. In some instances, acid in the ink eroded the parchment and made it thinner. When light illuminates the surface of such parchment, it can penetrate the thinner spots more easily. The processing technique applied to all images of the SPP is called “transmission ratio image”. The ratio of the numerical values of the same pixels in each image is evaluated: the transmission illumination image at 940nm by the reflectance image at 940nm. The newer writing shows up in both images and the constant feature tends to be reduced in contrast making it less visible. In the transmission image, more light makes it through the regions where the erased characters have eaten into the parchment. This produces an image that shows clear characters that are otherwise very difficult to see. Through the SPP, it was understood that the process of eating away at the parchment tends to happen mostly on the flesh side of the parchment, so that only the characters from one side are visible in the transmission ratio image. (Figure 2.7)

2.7.2 Supervised Processing

In cases where batch processing failed to produce legible results, the spectral data of the specific page was assigned for further investigation to participating image scientists who used a variety of statistical methods for selecting band combinations that would isolate and enhance different features (parchment, overtext, undertext). This time-intensive work requires custom combinations to be produced for each page, based most of the time on trial and error. Results obtained from such statistics vary when obtained from different numbers of spectral bands as well as different regions of the

image. The large number of possible variations together with long computation times are most time-consuming aspects of image processing (Easton & Kelbe, 2014, pp. 35–46).

Even before the statistical analysis of spectral images, an additional “preprocessing” step is often necessary. A particular technique – called “Blur and Divide” – is utilized to reduce spatial variations in image contrast. In this technique, two copies of the same image set are created. One copy is artificially slightly blurred, while the other copy is left untouched. The ratio of the gray values of the unblurred and blurred image is evaluated, and the resulting image is found to minimize some “noise” elements in the images.

The techniques mainly used for spectral image processing can be summarized as follows: Spectral Angle Mapping (SAM), Principal Component Analysis (PCA), Independent Component Analysis (ICA), Division of pixel values from two or more registered images of the same folio (Spectral Math), and Minimum Noise Fraction (MNF).

Currently, an imaging scientist has a variety of software tools available for the task of processing. Techniques and workflows of most of these tools were shaped by the intensive amount of data from the SPP.

- ENVI™, L3Harris Geospatial Solutions
- Adobe Photoshop™
- Matlab, Mathworks
- ImageJ
- Hoku, created by Keith Knox (Knox, 2021)

Brief guide through ENVI tasks:

1. Create image cube(s) from collected data.
2. Edit image header to include filenames AND wavelengths.
3. Use reference standards to calibrate gray values.
4. Display image(s), using various rendering options to look for features of interest and/or select bands that show features most clearly or prominently
5. Process data using one or more statistical algorithms (e.g., PCA, ICA, SAM, etc.).

6. Render and export processed images.

2.7.3 Processing: Lessons Learned

Different processing methods produce different results from the variety of the software tools that are available. But still the image scientists cannot (as yet) predict which method(s) will produce best result for any specific folio because of the many different physical attributes of parchment, inks and method of erasures. Yet, sometimes looking for what does not vary is better than looking for what does vary. Through the data collected from the curled Sinai manuscripts it is understood that raking light can highlight the surface topography to reveal the folio's past history. Whereas transmitted light can reveal eroded character shapes, not visible in ultraviolet. Finally, with every new manuscript, the SPP image scientists developed new methods to enhance or reveal characters.

2.8 Metadata

Metadata of the palimpsest manuscripts digital files are divided into two main groups: technical and descriptive. Technical metadata of images describe the capturing system as well as the image processing methods applied to raw files. This is critical information to permit scientific reproduction of the result from the same manuscript and establish objectivity of the initial text identification. Descriptive metadata describe not only the codicological format of the object and the visible writing, but also the erased undertext. For this reason, the scientists and scholars involved introduced new terminology for the description and database organization of the erased writings.

For the technical metadata it is important to document for each shot the exact exposure time of the shutter and lights that illuminated the object, i.e. the intensity of the LED lights used and the exact wavelength as well as the number of illuminating sources. This information is inscribed in the digital metadata including the light groups: MainBank, Transmissive, Filter Wheel, Auxiliary. The metadata also have to contain the model number of the capturing device, the model and characteristics of the lens, its aperture as well as the number of pixels in the sensor and the spatial resolution of the

image in “pixels per inch” (PPI). This permits reproduction of the image with exactly the same magnification and resolution.

The technical metadata of processed images need to include the methodology used in creating the file. An imaging scientist has the ability to record name, and method of processing, or even combination of methods that were used. For example, “PCA_band_2+ICA_band_1” means that the scientist after running a Principal Component Analysis, kept the second resulting band as well as the first resulting band of an Independent Component Analysis and combined them together by placing them on different channels of an RGB image, thus creating a pseudo color processed image.

For the codicological cataloging, the manuscript object was measured in its physical dimensions and the quire structure examined. This information follows the object until its online publication. For the description of the erased undertext, a new terminology had to be developed. This assisted participating scholars who could interact with the object only in its digital form through their computers without direct access to the physical object, whether bound or fragmentary. Clearly defined new terms, such as Text Layer Grouping, Undertext Object and Folio Undertext Layer, assisted in this effort. For each side of a palimpsest folio, an overtext and at least one undertext layer were assigned.

The descriptive metadata also note the percentage of visibility of the undertext by the naked eye of an observer, the characterization of the ink color and the undertext orientation. Other recorded information include evidence of palimpsestation, when present, such as pin prickings used to draw guidelines, any such lines themselves, and surface irregularities because of washing or scraping. A single folio may have more than one undertext layer (and therefore be double or even triple palimpsest), and each has to be recorded in the descriptive metadata. The documentation of the orientation of the undertext is, as already mentioned, important since imaging scientists and scholars who have access only to the digital data need to understand how the undertext is present on the physical object.

2.9 Online Publication

All color and processed images of the Sinai Palimpsests Project are available online, open access, at the webpages *SinaiPalimpsests.org* as well as at *Sinai.Library.UCLA.edu*. This is an online publication of Saint Catherine's Monastery. The University of California Los Angeles keeps a backup of the data for security reasons and hosts online images in high-resolution format. The scholarly and educational value is evident: any student is free to view, study, and perform research in any of the images available online. While quoting the data is permitted, publication of images from the data requires authorization from Saint Catherine's Monastery. The scholars of the Early Manuscript Electronic Library (EMEL) assisted the Monastery by building a registration platform that is free for all. This approach is called "responsible access": free access after acceptance of the rules and terms for requests for permission to publish images.

The online published data do not feature any kind of digital watermarking and are secured from unauthorized downloading by fragmenting the images in various magnification levels and resolution. When a user interacts with an image, he or she views the full image in lower resolution. As the user increases magnification, new images of higher resolution of the specific area of interest are loaded in the web browser. This is repeated for every step of magnification that a user performs. Images are compatible with IIIF standard. The opensource viewer is "Mirador".

2.10 An Unexpected Discovery in Sinai Arabic New Finds 8

To illustrate the potential for new research, I will describe an unexpected discovery made while imaging the manuscript Sinai Arabic New Finds 8. Approximately 34 hours (almost a week's work, not counting the frequent electricity outages) were needed to capture its 256 sides, i.e., both rectos and versos (Kasotakis, Forthcoming, 2021a).

In the captured images, some strange shapes were visible instead of the usual letters. The shapes resembled flowers and were barely discernible behind the Arabic overtext. Since the process of imaging a codex involves the capturing of all recto sides first and only then all verso sides, there was no possibility at this stage to see the pages as a

continuation. After completing the recto side and imaging the facing side, I again observed - even more distinctly - further strange shapes under the overtext on ff. 16 and 17. After Roger Easton processed the images on May 29, 2014, I was able to identify the name “phileterion” on f. 16v (φιλετέριον in the manuscript; corr. φιλεταίριον), a plant, and a text in Greek (lower left of the new image), describing how the leaves of phileterion boiled in oil could be used as a healing paste against scorpion bites. Quick research connected this finding to the “polemonium” described by the medical author Pedanios Dioscurides of the 1st century A.D. Polemonium still is the Latin name of this plant.

Πολεμώνιον, Polemonium, Greek Valerian (called by some Philetaerium), is attenuate and desiccative. Hence some give the root of it in wine for ischiatic disease, dysentery, and scirrhus of the spleen. [...] It occurs in the Hippocratic treatises (Hippiatr. 108, ed. Basil) but is not found in the works of Celsus. Dioscorides recommends it to be given for the bites of venomous reptiles, for dysentery, dysuria, sciatica, and diseases of the spleen, and also as a masticatory for toothache. He further mentions that it was used as an amulet for the sting of the scorpion (IV, 8). Our author copies from Galen, as does also Aetius. We have not been able to trace it in the works for the Arabians, with the exception of Ebn Baithar, whose account of it is made up entirely of extracts from Dioscorides and Galen (I, 186).” (Adams, 1844, p. 304)

A further check by Giulia Rossetto, participating scholar in the SPP, confirmed that the text was unknown to the existing corpus of Greek texts of the *Thesaurus Linguae Graecae* (TLG).¹⁹ Subsequent study of the illustration and the accompanying text by participating scholars Agamemnon Tselikas (Director, Centre of History and Palaeography of the National Bank of Greece Cultural Foundation) and Nigel Wilson (emeritus fellow and tutor in Classics, Lincoln College, Oxford) revealed that the illustrated folio undertext was written in a loose majuscule of small size in the 5th-6th century and may have originated from a herbalist prior to Dioscorides, possibly by the physician Crateuas (Kasotakis, Forthcoming; Rossetto, Forthcoming).

¹⁹ Personal communication with Rossetto, Giulia (2015).

This discovery conveys the excitement of being the first, in the imaging room, to recognize unusual features in erased layers of a text that can then be made visible through a long chain of interlinking steps. (Figures 2.8, 2.9)

Table 2.4

Transcription of an unknown erased medical recipe against scorpion bites found on f. 16v of Sinai Arabic New Finds 8

Erased Greek Text (diplomatic transcription)	English Translation
ΤΟΦΙΛΕΤΕΡΙΟΝΑ	The phileterion acts perfectly for those
ΚΡΩΣΠΟΙΕΠΠΡΟΣ	who are stung by a scorpion after
ΤΟΥΣΚΟΡΠΙΟΠΑΗ	having boiled some oil, and having
ΚΤΟΥΣΜΕΤΑΕΛΕΟΥ	used it to anoint the wound
ΕΨΥΜΕΝΟΥΚΑΙΚΑΤΑ	
ΥΤΗΣΠΑΛΗΓΗΣΑΛΙΦΟΜΕ	
ΝΟΥ	

2.11 A Few Numbers and Statistics

From the first SPP imaging session in 2011 until the 20th and last onsite session in 2015, the onsite team spent a total of 60 weeks in the Monastery. Librarians worked along photographers, imaging scientists, data managers, technicians and scholars. The collective effort of the more than 40 people involved resulted in the accumulated data now online as well as in new techniques for interpreting spectral data.

In the course of the SPP, the participating staff imaged 74 palimpsested manuscripts. From about 6800 pages in 11 different languages dating from the 5th to the 12th century, 200.000 raw images were captured, and 212.000 processed images generated. In terms of mass data, this translates into approximately 50 Terabytes, 25 TB of raw images and 25 TB of processed data. In terms of knowledge of the past, the SPP scholars identified 305 erased texts. From these the team extracted data about the distribution of languages as well as time of original production. This added mostly unstudied text from the first millennium CE to the corpus that scholars may use.

The recovered undertexts present a diversity of genres and content.

Table 2.5

Recovered undertexts from the Sinai Palimpsests Project

	Number	Percentage
Christian Textual Units	256	83%
Documentary Textual Units	4	1%
Unidentified Textual Units	36	12%
Classical Textual Units	11	4%
Total Textual Units	307	100%

Note. Christian Textual Units are divided into subcategories of genres: Biblical, Hagiographical, Theological, Liturgical, Apocryphal, Homiletical, Christian Poetry, Ecclesiastical History, Exegetical

In most of the undertexts, only a part of a larger work is preserved. In some cases, only a few lines from an unidentified work are visible. But even a few lines contribute in many important ways to the scholarly knowledge about the circulation and transmission of specific scriptural works – the texts or its authors had to migrate to the remote desert location – and to the history of languages and scripts used by monks in Saint Catherine’s Monastery. Even if scholars would deem a specific undertext of little importance, the interdisciplinary connections that can be traced reveal a larger picture of the mobility of contents and physical as well as the practical and, perhaps, spiritual or medical relationships of undertext and overtext. They reveal patterns of thinking in the distant past and in some cases, the known dating of an overtext may provide a better understanding and date-range for the undertext.

2.12 Conclusions

The efforts of a community of people collaborating in the SPP has not only added to scholarship, but also to the technological and scientific aspect of making inaccessible sources readable again through spectral imaging. The path of technological advancements from the 19th through the 20th and to the beginning of 21st century has been outlined and will continue. From the initial approaches of destructive interaction

with chemical treatment on the surface of a manuscript, to the experimentations with specified light-sensitive photographic emulsions, and application of filters in front of the capturing device. Followed by the introduction of digital technology for capturing readings of narrow wavebands, specific LED light sources, and the utilization of advanced computer systems for algorithmic processing.

In this ladder of scientific “ascension,” the SPP adapted advanced imaging techniques developed originally for remote sensing and medical research to humanities and humanity-orientated usages. The innovations of the Archimedes Palimpsest project, demonstrating the importance of spectral fluorescence in the recovery of erased texts - already a rare benefit for manuscript scholars - were expanded in the five-year funding for work in the collection of the Saint Catherine’s Monastery. Both the funding and the physical environment gave the imaging scientists the necessary space and access to raw data on the basis of which they could improve and supplement spectral imaging and processing solutions. The SPP team improved processes of the Archimedes Palimpsest project with specific purpose-built equipment as well as the transmissive illumination. These new techniques for multi-band transmissive illumination are now commonly used in other projects around the globe.²⁰

The next step for spectral imaging and for applying this technology to other collections is the reduction of cost in spectral capturing devices as well as the improvement in efficiency in terms of time needed to systematically capture a whole collection. On a limited scale, not only the recovery of palimpsested texts but also in the conservation monitoring of object conditions will be facilitated as well as recovery of sources damaged text by fire and water. On the large scale, the Sinai Library Digitization Project (Chapter 3) will push methodologies as well as accessibility and interpretation of rare sources farther along.

²⁰ Some examples: SFB 950 ‘Manuskriptkulturen in Asien, Afrika und Europa’ / Centre for the Study of Manuscript Cultures (CSMC) in Hamburg. ‘The Jubilees Palimpsest Project’ / St. Mary’s University in San Antonio and The National Endowment for the Humanities. ‘The Lazarus Project’ / University of Rochester in Rochester.

2.13 Figures of Chapter 2

Figure 2.1

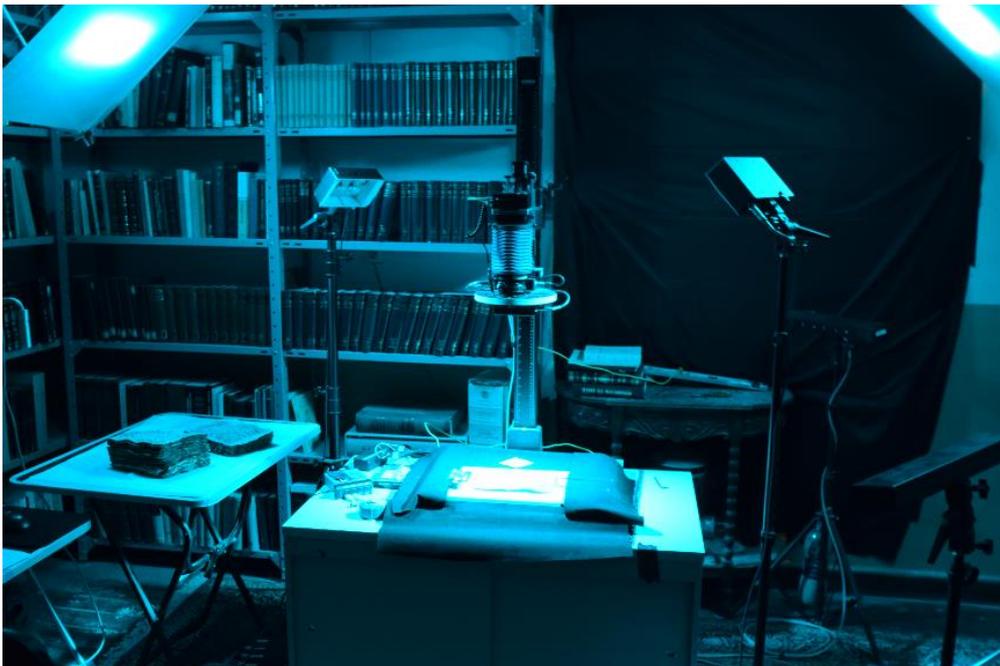
Spectral imaging system on Stokes cradle



Note. Camera, lens and filter wheel on right side, manuscript and calibration targets on left side of photograph

Figure 2.2

Spectral imaging system on copystand setup



Note. Camera, lens, filter wheel in the center, manuscript rests flat below camera, lights on the right and left illuminating with cyan light the object

Figure 2.3

Diagram displaying different positions of the spine of a bound object and the design of the Stokes book cradle to accommodate them

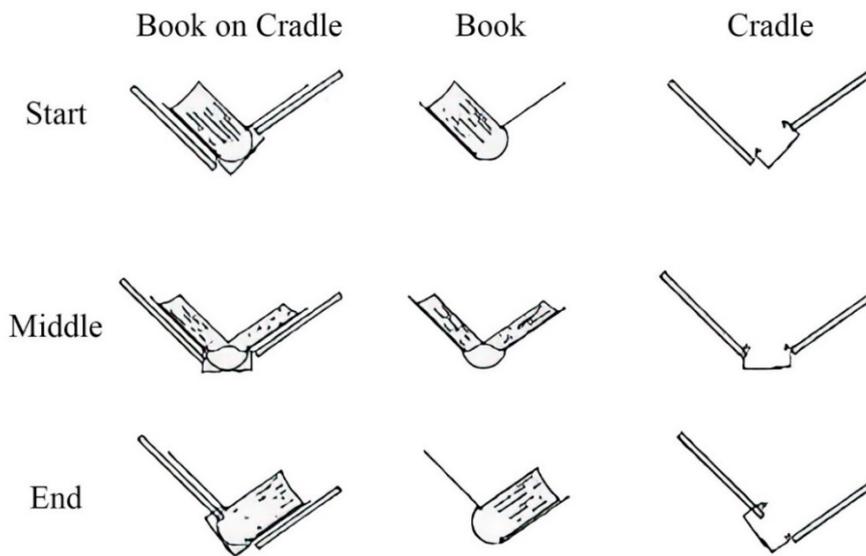


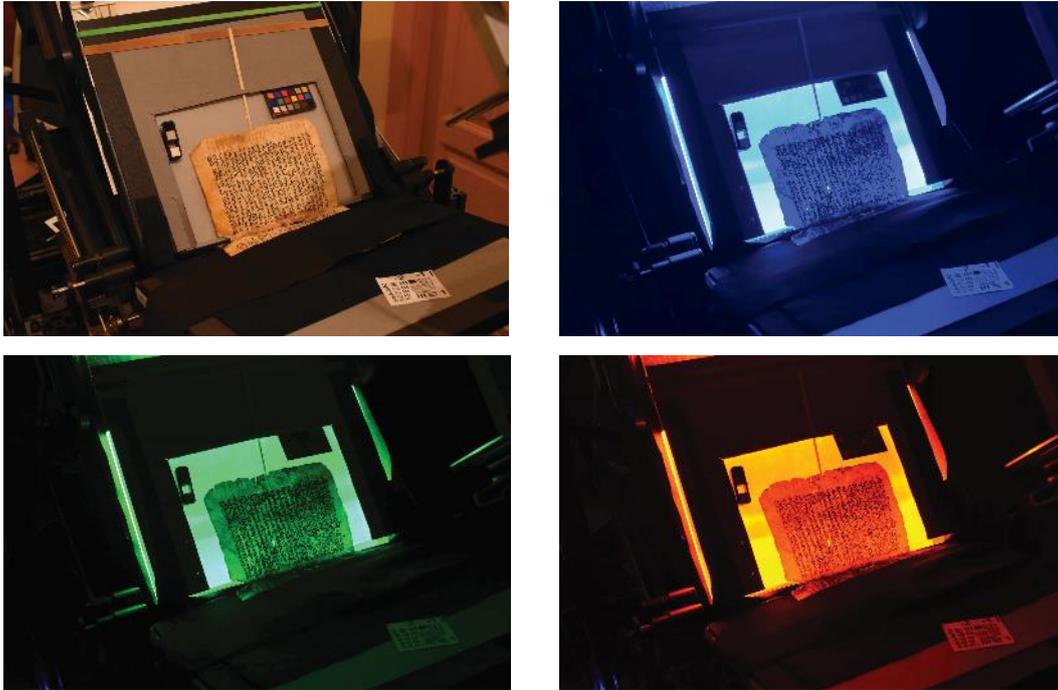
Figure 2.4

Imaging sequence of 33 shots from the same page and resulting color picture



Figure 2.5

Manuscript under different wavelengths of light



Note. (top left) manuscript under room light, (top right) blue light, (bottom left) green light, (bottom right) orange light

Figure 2.6

Pseudocolor image created from combination of 365nm and 780nm images



Figure 2.7

Transmissive image of ink that has eroded the parchment and light shines through the erased letters of Sinai Georgian NF 13, fol. 59r

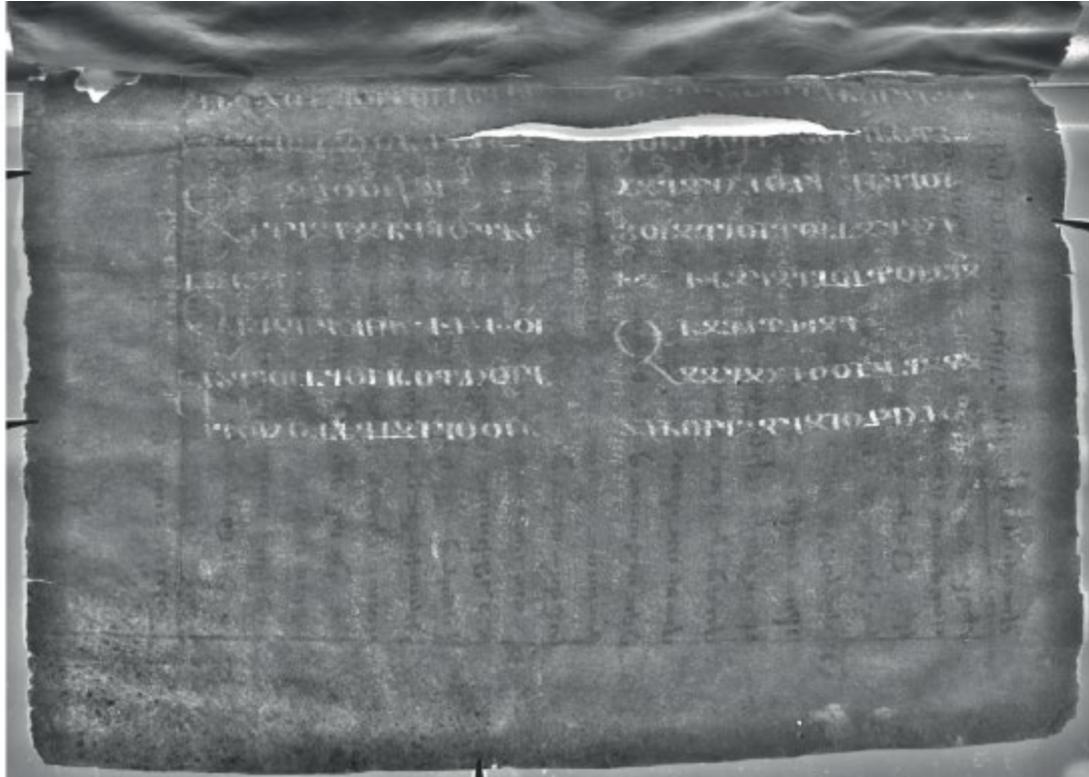


Figure 2.8

Phileterion, color image of Sinai Arabic NF 8, ff. 16-17, captured under visible light

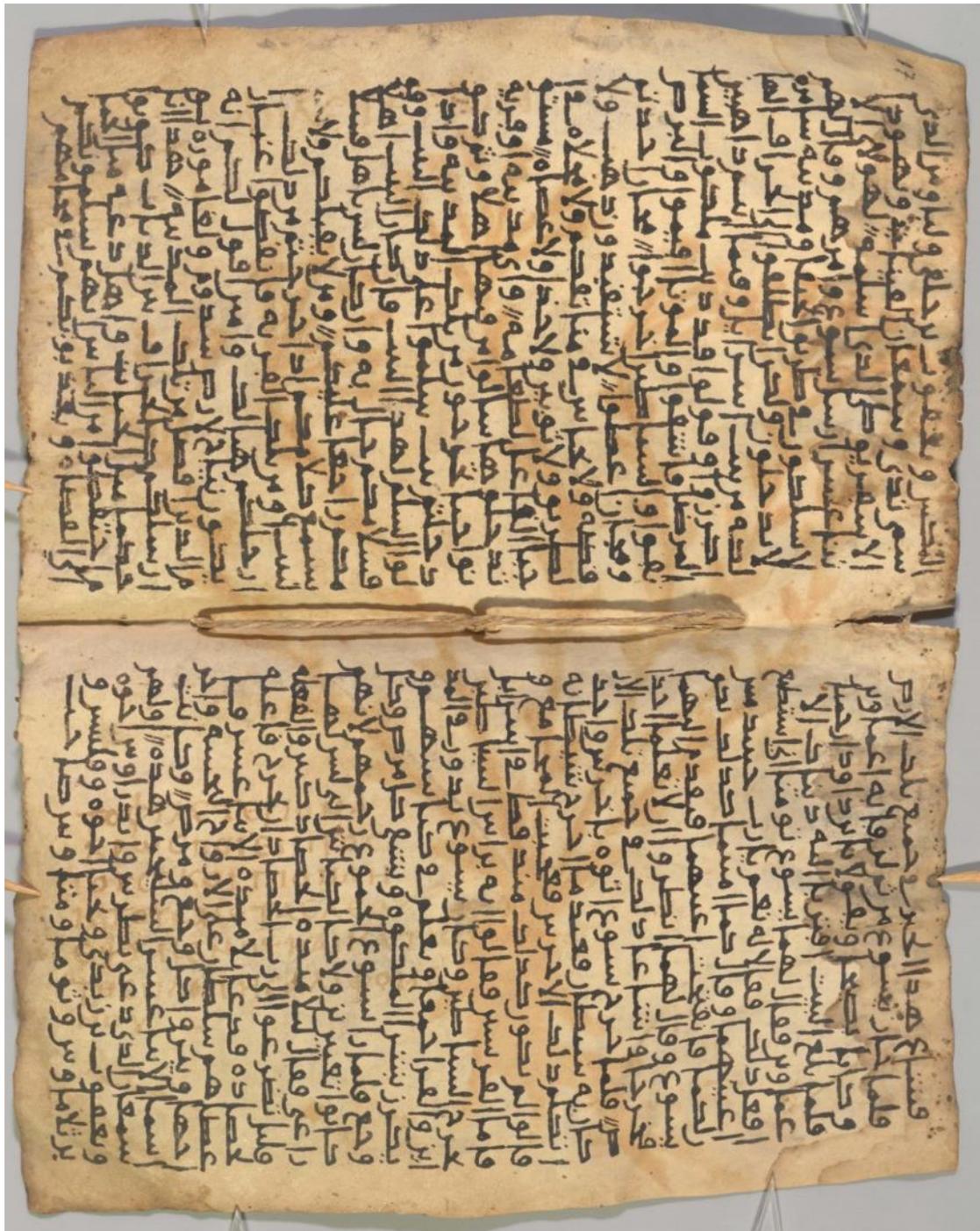


Figure 2.9

Phileterion, Sinai Arabic NF 8, ff. 16-17, processed by Roger Easton Jr. reveals a pharmaceutical recipe



3. The Sinai Library Digitization Project

The “Sinai Library Digitization Project” (SLDP) is the first imaging approach to the collection of manuscripts in the Library of Saint Catherine’s Monastery as a whole. Using new digital technologies and storage media (Chapter 3.4) it will present the collection as a publication of Saint Catherine’s with the collaboration of the Early Manuscripts Electronic Library (EMEL) and the University of California Los Angeles (UCLA). This large-scale digitization effort which took off in 2018 builds on the experience of EMEL and UCLA through the “Sinai Palimpsests Project” described above in Chapter 2. In several locations, most famously the Library of Congress (LoC) and the National Library of Israel (NLI),²¹ digitized versions of Sinai manuscripts exist but these are digitizations of decades-old microfilms and they do not include the most recent addition of the more than 1200 “New Finds” from 1975. In addition, microfilm only captures some 18 shades of grey and as a result the digitized black and white microfilms lack color and high magnification capabilities necessary to better describe a manuscript, its codicological features and its condition. Damaged folia and leaves with small script are illegible and the alternation of black and red inks, important in liturgical manuscripts, cannot be seen in the monochrome images. Having a complete, reliable and high-quality set of images of the Sinai manuscripts has been the desideratum of the scholarly community for decades, especially because of the remote location of the Library. Thus, the new digital Library to be created by the “Sinai Library Digitization Project” will bring together in one location and in high-quality the extensive manuscripts collection of Saint Catherine’s and make it easily accessible to researchers.

Building from experiences of the past (SPP) and learning from the study of expeditions from the 19th and 20th century, the Sinai Library Digitization Project (SLDP) processes mass data on a new scale in such a remote location. The initiators built a solid foundation over two years of planning and of strengthening the relations between international collaborators and the local monastic community. The project aims at both, providing digital copies of the physical objects and search functions that will permit

²¹ See more on this in Chapter 1.3.7 and 1.3.9.

scholars to find, compare and study the manuscripts' content. This work is supported by building descriptive metadata and accurate databases.

By the time of the writing of this dissertation, SLDP is an ongoing project divided into two phases. Phase one (2018-2021) aims to digitize the entire Arabic and Syriac collection of manuscripts that can be calculated to approximately 400.000 photographs. Phase two (2021-2027) will include the Greek, Georgian, Slavonic, Ethiopian, and Persian collections of about 1.100.000 additional photographs.²² Further language groups exist in Saint Catherine's Library, but have been mislabeled or by mistake incorporated in the language groups mentioned above, a situation that emphasizes the importance of better information and metadata recording.²³

The governing body of the Monastery composed by His Eminence the Archbishop of Sinai Damianos, and the Holy Council [Ιερά Σύναξις] approved the project in 2015. So far, the project is supported by generous donations from the Ahmanson foundation, the Arcadia foundation, the Museum of the Bible, and smaller benefactors that wish to remain anonymous.²⁴ The project leadership represents all three partners of this digitization effort. Father Justin Sinaites, who as the Librarian of Saint Catherine's has been spearheading digitization of the Monastery's manuscripts for the last 20 years, realized that completion of this work in a timely manner requires an organized and dedicated team of people. Father Justin is directing and supervising all onsite digitization as well as providing critical support on material handling based on his vast and unique experience with the collection. Other directing personnel include Michael Phelps of EMEL (executive director), Dawn Childress of UCLA (director), and Damianos Kasotakis of EMEL (director of imaging). The whole is supported by the Egyptian Ministry of Antiquities and its local representatives.

²² "Photographs" refer to individual shot taken (and, perhaps, printed out), "images" refer to the digital files.

²³ A famous example is of Sinai Slavonic 5 which actually is a Latin manuscript (*Image 4 of Slavonic [Slavic] Manuscripts 5. Psalter [Psaltir'] (Latin).*)

²⁴ Ahmanson: (*Grants | The Ahmanson Foundation*), Arcadia grant number 360G-ArcadiaFund-3977.

3.1 In Preparation of a Big Data Project

The digitization project is a multiyear effort utilizing heavy and bulky highly sophisticated equipment, where both remoteness and technology guide the designing and implementing of the installations. Space is an issue in the Byzantine fortress built in the 6th century. It has to meet the following criteria: proximity to the Library, sufficient space for multiple workstations and people, steady floors not affected from vibrations caused by walking or heavy equipment, connection to a reliable electrical network, and ability to accommodate several people at the same time without negatively affecting the humidity of the room, meaning that air circulation must also be taken into account.

On the basis of these requirements, in 2018 a room in the south-east corner of the Monastery was selected on the ground floor of the newly renovated three-story wing that houses the modern Library. One of my contributions to the project was designing and implementing a floor plan for all equipment and workstations, as well as solving issues of accessibility, air flow, network, and electrical wiring. The room with the dimension of 8.7 by 7.8 meters and a ceiling four meters high, was reconditioned during the renovation works, all windows and doors (except for one main entrance) were sealed and the room was fitted with metal racks for the housing of all of the manuscript collection stored inside big plastic boxes. On its south-west corner the room communicated to an internal staircase that leads directly to the Library located on the 2nd floor. Two previously sealed windows, one of them an original 6th-century, were opened to provide optimal airflow with controls to avoid dust inflow. The reopened 6th-century window cuts through the outer wall of the Monastery and permits overlooking the valley and mountains to the east. Having internal connection through secure corridors and rooms to the main Library is critical in the moving of the objects from and to the digitization workshop. (Figure 3.1)

Planning a large-scale technological project in the middle of the desert involves difficulties not be present in an urban and accessible environment. Only in recent years has Saint Catherine's Monastery been connected to a local electrical grid, which relies on big petrol generators built to accommodate the needs of several Bedouin villages. The condition of the network is poor as it was not designed for the increasing demands of tourism and of modern electrical devices. Even though Egypt belongs to the group

of countries providing a stable 220 volt current, the actual readings at the Monastery are between 136v to 173v. This constant undervoltage tends to destroy backup battery units since the internal current stabilizer is not designed for such intense operation. In addition, the frequent power outages demand the constant operation and charge-discharge cycle of such battery units. To solve similar issues, in 1950 the Library of Congress team brought two diesel generators and the same strategy was followed by the team of the National Library of Israel in 1969. In the course of the SPP, the team realized that backup battery units would quickly deteriorate because of these conditions and this experience is being used in the planning of the SLDP.

A stabilizer of 5000kVA was installed to stabilize electrical current to a constant 220 volts. The stabilizer connected to 3500watt uninterruptible power supply battery unit (UPS) which provided support for all sensitive electronics. All wiring is done with a 3 x 3mm cable (3 entwined cables for Live, Neutral, Ground of 3mm diameter each) connected to a 30-ampere fuse. This setup provides security against towards electrical fire hazards due to overloading. The battery unit can provide 30-40 minutes of uninterrupted operation for one imaging workstation in case of a power outage, or 10-20 minutes for all four.

The next fundamental step is network connectivity between electronic devices. All imaging workstations need to be able to connect and store captured data to a secure centralized repository. For this a local area network was designed based on 10Gbps connectivity.²⁵ This speed ensures fast transmission of data from and to the imaging workstations and the central storage server and prevents bottlenecks thus ensuring an uninterrupted and optimized workflow. (Figure 3.2)

As mentioned above, the central data storage server has a crucial role of securing digital files, but also assisting in the quality control of captured images. While an imaging workstation is photographing an object, another computer can access the stored data and verify the quality and integrity of the photos. The current storage server has a capacity of 180Terabytes (TB), with possibility of future upgrade to double the amount. This storage can secure a local copy of all data of phase one for the Monastery, as well as captured and processed data of the SPP (~50TB). Each of the image capturing

²⁵ Network data transfer speed based on the IEEE 802.3an-2006 specification standard.

workstations is not only connected to the main data repository but also saves data captured to each own local RAID array (an external set of storage hard drives that is able to operate even if one of the drives fails, without losing any data).

For the acquisition of images, four digital photography workstations were acquired. Two of them have two cameras each positioned in a -V- shape, so that recto and verso images can be captured simultaneously from an open book. Two monitors mounted to the operator's left allow him to see these images to check for alignment and focus. The lights are calibrated for correct color capture and balance based on Golden Thread color calibration techniques.²⁶ The original workstations have been considerably altered for use at Saint Catherine's Monastery. A -V- shaped cradle of 100 degrees opening allows safe photography of manuscripts without any damage to spine or folia. These two workstations are used to photograph manuscripts that open more easily. (Figure 3.3)

For safe photography of manuscripts that are more fragile or that are more tightly bound, the other two workstations make use of a single camera that is mounted on a track, to allow the camera to be moved and focused. The manuscript rests on platens, each adjustable in height so that a codex may be imaged from front to back without subjecting the binding to any strain. The camera, perpendicular above the horizontal manuscript, photographs one leaf at a time. Thus, this system is slower than the workstations with two cameras. The cameras on both systems are PhaseOne digital cameras with 100-megapixel CMOS sensors. (Figure 3.4)

Manuscript objects selected for digitization need to be safely secured and identified easily in the imaging room. For this reason, three small storage spaces are created: a box holding the manuscripts taken from the Library for digitization, a box for manuscripts in the process if the daily imaging session has to be interrupted, and a box for all manuscripts for which digitization is complete and that are ready to be returned to the Library.

To bring together all of the components mentioned above, I have created a workflow of the digitization procedures specifically for the SLDP that will be analyzed below.

²⁶ Golden Thread software and color targets are a product of Image Sciences Associates (ISA) meeting FADGI and Metamorfoze Cultural Heritage Imaging standards.

The first phase of the digitization workflow is manuscript categorization based on conservation condition and difficulty of digitization. This part is discussed next.

3.2 Evaluation of Equipment and Approaches from a Conservation Standpoint

Some 75% of the Sinai manuscripts can be photographed using the workstations with two cameras. Some 20% of the manuscripts need to be photographed on the workstations with a single camera. And about 5% of the manuscripts cannot be photographed safely in their present state. These will need to be set aside until a proper conservation workshop has been installed in the Monastery.

Only by the collaboration of many specialists was it possible to arrive at the numbers of individual photographs above. With the extensive understanding of the whole collection, Father Justin was able to do the original categorization of manuscripts as “easily” imaged, “difficult” and “not possible at the current state” with the help of Michael Phelps and myself.

As consulting conservators from Greece, Konstantinos Choulis and Vasiliki Kokla,²⁷ inspected onsite not only the manuscripts to be digitized, but also reviewed the digitization systems and procedures before the actual start of the imaging in March of 2018. They checked for potential hazards to the manuscripts including obstacles like cables on the floors along which manuscripts would be carried from Library to imaging station. Also, they suggested a dedicated space for manuscripts that remain temporarily in the imaging room.

Environmental conditions to be evaluated included room temperatures since it is imperative to avoid exposure of manuscripts to abrupt changes in Temperature (T°) and Relative Humidity (RH). The climatic conditions in the digitization room should not deviate beyond a small level of tolerance from those in the Library’s permanent storage area. With the help of specialized data loggers, Librarian Father Justin recorded measurements of Temperature and Relative Humidity in the two rooms (storage and digitization) between 16/3/2018-22/5/2018. The table below shows that the archive is

²⁷ Both from the University of West Attica | TEIATH, Department of Conservation of Antiquities and Works of Art.

the most stable room. Temperature from high to low ranged only six degrees, and humidity ranged from high to low only 4.6 percent. The outside, by contrast, ranged in temperature from high to low 22.3 degrees, and as regards to humidity from a low of zero (during high winds) to a high of 68.3 percent. The manuscript storeroom and the photography room are also very stable, if not quite as stable as the archive. (Figure 3.5)

Table 3.1

Values of Temperature and Relative Humidity in the manuscripts storage room, the digitization room, and outside

Area	Unit	Low	Mean	High	Range
Archive	Temperature	18.8	21.6	24.8	6
	Humidity	24.0	26.3	28.6	4.6
Library	Temperature	18.5	21.1	24.8	6.4
	Humidity	15.3	26.9	35.0	19.6
Outside	Temperature	9.5	20.2	31.8	22.3
	Humidity	0	18.8	68.3	68.3
Photography	Temperature	17.8	19.9	22.7	4.9
	Humidity	13.3	25.4	28.3	15.0

Note. Recorded between 16/3/2018-22/5/2018.

From the detailed inspection of all the manuscripts in the Arabic and Syriac collections the following statistics were collected: 891 mss (manuscripts) in Category 1 (76%), 169 mss in Category 2 (14%), 69 mss in Category 3 (6%), 68 mss in Category 4 (6%). (Figure 3.6)

- Category 1: manuscripts whose preservation condition allows them to open normally.
- Category 2: manuscripts that do not have particular opening problems, but have intense waves on the substrate material.
- Category 3: manuscripts that present serious opening problems and show intense wear.
- Category 4: manuscripts with significant problems, which will not be digitized at this stage.

3.3 Workflow

Imaging of large numbers of manuscripts is a tedious process, because of the repetitiveness of the work. At the same time, the operator must remain quite alert, because of the fragility and the importance of the manuscripts that are being photographed. Working from 8:30 AM to 4:00 PM, with half an hour for lunch at 12:00, for six days a week, can be very fatiguing. The team of photographers works at the Monastery for four weeks and then returns to Athens (Greece) with the set of data which in the subsequent four weeks they process, correcting images for alignment if necessary, checking them for sharpness, and creating derivative images from the RAW files of the image capture, which are then shipped to UCLA. They then return to the Monastery for another work session, bringing with them a set of the processed images. In this way, complete sets of the images are stored in three different geographical locations (Egypt, Greece, U.S.A.).

The workflow of the project is governed by the “Sinai Library Digitization Project Documentation 2.0” (2.0 stands for the current revision of the document). While drafting this documentation and designing the workflow I kept in mind the experience gathered from historical sources, past projects in which I participated, as well as very useful feedback that I gathered from onsite visits to the digitization departments of the Vatican Library (2018), Cambridge University Library (2018), and the Royal Library of Denmark (2018).

The work is divided into several phases: beginning and end of an imaging session, beginning and end of imaging day, operation of PhaseOne BC100 (Book Cradle 100) imaging station, operation of Stokes PBC (Preservation Book Cradle) imaging station, backup procedures, image processing and quality control, metadata recording, and finally delivery of finalized product. Below is an overview describing the steps of digitization from the physical object (the manuscript) to the digitized final product ready for delivery to UCLA, which will in turn process it for online publication. (Figure 3.7)

In the beginning of each imaging session the team starts by cleaning all working spaces and equipment. Electrical current is turned on for the stabilizer, the battery unit and all power strips. Equipment is visually inspected for flaws and maintained if needed, for example tightening of screws or plugin of cables that are loose. In the reverse order, at

the end of an imaging session it is first verified that all data are transferred from the local storage devices to the main storage server. A checksum list of digital signatures of all files are generated from the server.

For the beginning of each imaging day operators first and foremost must wash and dry hands in order to not transmit oils or dirt to the surface of the handled objects. This step is advised to happen multiple times a day. All ceiling lights of the room are turned off in order to minimize micro-interferences with the illumination of the captured object, thus altering the color accuracy results. Cameras and capture computers are switched on. For the BC-100 system, the cradle is reset in a central position. For the PBC the electronic motors of the cradle need to be switched on and the operator needs to wait until the system auto-calibrates itself by testing the motors rotations. Lights are switched on, and from the capture computer the electronic shutters must be initialized by selecting them on the Schneider software. Lens covering caps are not removed before a black levels calibration that the operator needs to do during the first capture of the day. The camera captures a picture with the lens receiving no light (since the cover is still on) and calibrates noise levels of the resulting photo based on the absence of light.

The operator needs to verify that the aperture is set at an $f/11$ value. This value has been tested to provide sharp results for the specific lenses used and adequate depth of field for manuscripts with bent or curved folia.

Next, the capturing software is started and the operator needs to create a new imaging session for a new object or load a previous one for an object that has not yet been finished. Filenames are set anew or verified if continuing previous work. Only then is the operator ready to begin capturing images for the day.

At the end of an imaging day, small marks are placed on the exact position where the object rests on the book cradle, in order to be able to reproduce the same position the next day once the object is removed (marks can be small pieces of paper resting along the edges of the object, creating a frame). The object is then removed and returned to the secure predetermined location. Capturing software and computer are turned off after verifying that no active process is running. The digital cameras are powered down and cover caps are placed on the lenses to block dust from settling. All obstacles are removed from the room, tools returned to predefined positions, the room is cleaned,

and the electricity is disconnected from the battery unit and stabilizer. Optionally, electrical current can be switched off from the central panel fuses. This is repeated at the end of each imaging day.

At the beginning of imaging a new object the following steps take place in the exact listed order. Identification of the object to be imaged, followed by the collection of physical and descriptive metadata for the population of fields in the project's database. This includes the measurement of physical dimensions and weight, as well as recording the genre category of the contents of the object according to existing catalogs. Preparing for the technical photography, a new folder is created that will store all captured images on the local computer. The camera is then calibrated in three ways: even illumination, white balance, and exposure. By creating custom LCC profiles the camera can artificially illuminate evenly all of the scene it is capturing. To do so, a white flat surface (A3 non-glossy white paper) is placed on the scene and a picture is captured. The camera then maps the scene levels of the picture for every single pixel, and in turn equalizes the numbers so that darker areas become brighter, and too bright areas are toned down, thus creating an evenly illuminated scene. Later the white paper is removed, and a set of color targets is placed on the scene. The operator captures an image and calibrates the exposure of the camera based on readings of the white and grey patches. These patches are pre-calibrated from the manufacturer of the targets and their values are recorded on them. The operator measures with a digital tool the values of the digital picture on the spot of the patches and makes changes in the exposure times of the camera, if needed, in order to match the recorded values. Similarly, white balance is performed by pointing the capture software to read the color temperature of white or grey patches from the captured targets.

Color targets have printed rulers on them in pixels and centimeters. From the digital captured image, the operator measures the distance between a single inch and the software can count all the pixels between the two points predefined from the operator, thus calculating the captured resolution in pixels per inch.

Once the imaging system is calibrated, the object is placed on the book cradle. Each manuscript object is different in size and volume. Book cradles of both the BC-100 and the PBC systems need to be re-positioned for each individual manuscript. This is done in order to maximize the safety of the object while it rests on the cradle. On the BC-100

the two sides of the -V- cradle may be adjusted to accommodate thicker or thinner objects. In a similar way the PBC's platforms for the object are moved closer or farther from each other, creating a larger or smaller gap in accordance with the spine of a bound manuscript.

After the completion of the digitization of an object the operator revisits the project's database and updates it based on notes acquired during or at the end of the imaging. Foliation anomalies are noted, and the total number of shots and folia is precisely calculated with the use of a computer program (Chapter 3.5)

All captured data are transferred and backed-up, at the beginning of each new imaging day. Using pre-configured scripts with the open-source software FreeFileSync, each capturing station copies the data of the previous day to the main storage server. On average, each imaging station will produce and then transfer ~50 gigabytes of data per day. An imaging session with the four stations in operation collectively generates 4-6 terabytes in 22 days of image capturing.

From the storage server a secondary copy is created on external hard disk drives and thus the data are physically transferred from the Sinai desert to the image processing center in Athens. There, with two image processing workstations and a second storage server installed, the operators perform cropping and correct the orientation on all images. They then export the results to archival format TIFFs and finally embed metadata on each image before transferring it back to Saint Catherine's Monastery (Egypt) and UCLA (USA). Since this quality check takes place between imaging sessions in the Sinai, errors found can be corrected immediately or, if necessary, manuscripts can be re-imaged during the next imaging session.

This workflow, as demonstrated in figure 3.7, creates a feedback loop between the operators and their work and has multiple verification steps that attempt to check data integrity and catch human errors before the online publication of an image. Filenames are checked in an automated way; shots are counted by computer scripts and these programs notify operators to inspect closely cases where a mistake seems to have happened.

As the workflow described above demands a lot of technical preparation, the focus of the next section will move to the technical details.

3.4 Digitization Technologies

From a technical standpoint the digitization equipment is divided into two categories: book cradles for the support of the manuscript objects, and digital photographic systems. Book cradles are designed to keep an object still but also safe while it is being imaged. The two main systems are, as described above, the PhaseOne BC-100 (Book Cradle 100) for use with non-fragile objects, and the Stokes PBC (Preservation Book Cradle) for use with fragile objects. Both systems were modified and tailored to the needs of Saint Catherine's collection.

3.4.1 Book Cradles

The BC-100, in normal usage, has a -V- shaped cradle at 100 degrees which holds an open book. In turn the user lowers a glass plate also in -V- shape that flattens by pressure the pages of the object. The cradle sits on a suspension system of four springs that pushes the object continuously upwards onto the glass surface. Under conditions of modern books this is a safe practice, but for the Sinai collection it raises several concerns: the pressure could damage the fragile book bindings, and the glass could make dry inks flake off the pages through static electricity. For these reasons, a completely new approach was designed by EMEL and the librarian of Saint Catherine's. A pneumatic system was installed under the -V- book cradle which could be operated to raise or lower an object towards the glass plates using a dial that can control the speed of the motion. In turn the glass platens were removed and replaced by anodized aluminum bars that were fitted inside the rails of the glass supporting frame. These bars can move vertically and horizontally and create a smaller frame around the object, from there small holding sticks can be mounted that hold down the pages and set a standard reference point so that the object always keeps the same distance from the camera. The pneumatic mechanism can bring the object closer or farther away from the sticks as the bound object is digitized. (Figure 3.8)

Two cameras are mounted to the long ends of the station at a 90 degrees angle from each side of the open book. Since the cameras have to remain parallel to the page, they move on a fixed and calibrated rail that extends from the frame of the BC-100. Lights

are mounted on the top-center of the station illuminating evenly all the surface of the object. Two computers are placed vertically side-by-side in order to present the captured images as an open book to the operator. Control of the shutter is done by dedicated buttons placed in front of the operator.

Advantages of the BC-100:

- Efficient workflow, as two pages are imaged with the press of one button.
- Object does not open more than 100 degrees; thus, the spine is not put into intense stress.
- The system can also accommodate manuscripts that exhibit intense surface bending of the substrate with the use of retaining sticks that extend from the aluminum custom frame.

The Stokes PBC is a single camera book cradle. Priority in this system is the safety of fragile codices as it eliminates stress to the binding during the photographic process and supports individual pages in a way that maintains a constant focal plane and avoids keystone effect (peramorphosis of rectangular objects caused by not maintaining an absolute parallel between the sensor and the object surface). The cradle can support a bound object in an adjustable -V- shape open from 85 to 120 degrees. All rotation abilities of the cradle are adjusted by computer-controlled stepping to the natural movement of the manuscript's spine as its pages are turned and its weight shifts. This rotational movement eliminates stress on the centuries-old bindings. The operator may also accurately control the rotation manually to ensure that the object rests comfortably on the cradle at all times. On the other end of the book cradle is the photographic system in a 90-degree angle from the page to be imaged. The system itself is tipped at a 45-degree angle from the floor, in an effort to evenly distribute the weight of both sides of the object (front and back) as it is being digitized. Book bindings of up to 10 inches thickness are supported, and pages up to 12 inches width and 17 inches height can be stabilized on a plate using light air suction. The use of suction is controlled and optional. At the same time, the opposite page, which is not photographed, is covered and held with artificial leather material that is harmless in contact with the writing substrate

(chemically stable and inert). Artificial leather also does not develop electrostatic stresses and thus does not attract suspended particles from the atmosphere (dust).²⁸

Advantages of the PBC:

- There is no pressure on the spine of the manuscript, which remains relatively free. The entire set of pages that have not yet been photographed do not come into contact with the surface retaining the page being photographed as the support surface "isolates" the individual page being photographed.
- Air suction to hold the sheet is not mandatory and works well with flat paper surfaces.
- In cases where the pages of the manuscript are subject to intense curvature, it is possible to apply an auxiliary cardboard frame from which sticks can be mounted to retain the waves of the pages.
- For bulky manuscripts (spine > 7 - 8 cm), the system offers the possibility of moving the page's support surface apart from each other, in order to accommodate the large surface of the spine safely.
- The supportive metal surfaces of the manuscript, and the exposure and retention surfaces of the page for more protection are covered with guaranteed and harmless materials such as plastazote and artificial leather, suitably stocked with Velcro.

This description has focused on the technical equipment, but it also indicates to what degree the operators need to be experts in understanding each and every object in its specifics as to avoid not only damage but even stress. As described above, specialist conservators, the librarian and the EMEL directors are categorizing the objects before the camera operators take over or, in other words, care for the manuscript.

3.4.2 Imaging Sensor

For the capture of digital images, all workstations utilize the PhaseOne IQ3 100megapixels CMOS sensor. With dimensions of 53.7 x 40.4 mm this medium format

²⁸ The Preservation Book Cradle (PBC) is built under a patent license agreement with Alan Buchanan Designs, Ltd.

full frame sensor is 2.5 times larger than a regular 36 x 24 mm DSLR (Digital single-lens reflex camera). The bigger surface of the sensor enables it to capture more accurate details and light as the 100 million pixels have each a 4.6 x 4.6-micron size. Images can be captured with up to 16-bit color depth that produces a natural texture and accurate tonal feel. An important feature of this camera is the incorporation of an Electronic Shutter (ES), which can replace the operation and wear of a physical shutter by enabling and disabling in a predefined exposure time the operation of the sensor as it captures light during a shot. As it does not depend on mechanical parts it produces repeatable results throughout the operation lifecycle of the camera. The resulting digital image has dimensions of 11608 x 8708 pixels which can produce a 49.1 x 36.9-inch picture at 600 pixels per inch (PPI). The camera transfers all data directly to the capture computer through a USB 3 connection cable and can operate constantly without the use of a battery by being connected to electricity through a dedicated power cable. The operating temperatures of ~50 degrees Celsius are inside the normal operation spectrum of CMOS sensors but do require a calibration of black levels from time to time. This is performed on every power-on of the camera.

3.4.3 Light Sources of Digitization Systems

BC 100s utilize the “Digital Transition Photon” light sources. Each system is equipped with two identical LED (Light-emitting diode) units, which illuminate the manuscript at an angle of 45 degrees and a distance of one meter. The lights operate at color temperature of 5600° Kelvin (Daylight). These light sources hold Certification CE Lighting Industry Association TS32 Essential Requirements for Lighting²⁹ and score 98 at the Color Rendering Index (CRI).

For the Stokes PBC there are two LED light sources manufactured by Stokes Imaging, measuring 24 x 24 inches. The lights operate between 400-700nm and illuminate the manuscript at an angle of 45 degrees and a distance of 1.50m.

²⁹ 2014/35/EU Low Voltage Directive, 2014/30/EU Electromagnetic Compatibility Directive, 2014/53/EU Radio Equipment Directive, 2009/125/EC Energy Related Products Directive, Reg. 1194/2012/EC Directional Lamps, LED Lamps, Related Equipment + Amd 2015/1428/EU, 2011/65/EU Restriction of Hazardous Substances (RoHS) Directive.

The lights combine multiple frequencies of narrow bandwidth LEDs to produce a continuous visible spectrum of light without emitting radiation in the ultraviolet and infrared range of the electromagnetic spectrum. This ensures that emitted radiation does not contribute to the further deterioration (aging) of the writing substrate, the inks and the pigments, and heat is not released onto the photographed page.

3.4.4 Lens

Two lenses are used: the Schneider APO-DIGITAR 90mm/4.8 and the Schneider APO-DIGITAR 120mm/5.6. Both lenses are operated at an f/11 aperture which regulates the amount of light that passes through during a shot.

The 90mm lens gives a broader field of view from a fixed position and can accommodate larger manuscripts, whereas the 120mm lens from the same distance has smaller field of view and works better with smaller and more detailed objects.

These lenses are specifically designed for large format digital cameras. Build for accurate reproduction photography they minimize effects of distortions, and keystone (the keystone effect is a distortion that makes a square appear as a trapezoid).

3.4.5 Shutter

All imaging systems in the Sinai utilize Schneider Electronic Shutters -0-. This shutter controls both the aperture opening as well as the exposure time. It can communicate directly to the capturing computer so that settings and control commands can be sent through a USB cable. In cases in which the onboard electronic shutter of the digital sensor is used, the physical shutter acts as aperture controller and can be fully closed or open during calibration or focusing procedures. During black levels calibration the sensor must remain dark with no input of light, so the shutter can be closed from the user. In cases where the user has to fine-focus on the surface of the object, the shutter can be set to its most open setting (f4.8 or f5.6) in order to minimize the depth of field and make the focusing task much more precise to the eyes of the operator and thus more accurate as a final result.

3.4.6 Color Calibration

A primary challenge for RGB (Red, Green, Blue) photography is color accuracy, since images are generated from a sensor that is covered by three filters: Red, Green, and Blue. All other colors of the visible spectrum are a combination of these three colors.

Even expensive accurate color reproduction cameras present this challenge, regardless of pre-calibration by the manufacturer. Smaller or larger variations exist from one imaging setup to another, a small angle change in the lights, different distance of the sensor from the scene, or even environmental conditions that could generate noise on the imaging sensor.

The solution is the adoption of *in-situ* color profiling for RGB systems. A combination of the ColorChecker SG (*X-Rite Color Management, Measurement, Solutions, and Software*, 2021), the Golden Thread (*Image Science Associates*, 2021), and the SuperChroma HR-1 (Rodriguez, 2019) color targets is used to calibrate each of the imaging sensors that is coupled to specific set of lights and lens. Calibration software BasIColor (*Color Management Solutions | BasIColor | Engineering Office Dipl.-Ing. Karl Koch*, 2021) is used to generate an ICC (International Color Consortium) color profile for each camera setup.

To monitor deviations during the imaging process a small X-Rite ColorChecker (*X-Rite Color Management, Measurement, Solutions, and Software*, 2021) is present at the edges of each captured image.

3.5 Supporting Software

Supporting software are digital tools created specifically to assist in the SLDP workflow. These tools help resolve, document or automate critical tasks that would otherwise be time consuming. It was my task from the experience of the SPP workflow as well as observing the needs of the daily tasks of the SLDP to plan and create these tools.

3.5.1 Tool 1: Metadata Database and Progress Tracker

The progress workbook in the form of a database designed in Microsoft Excel serves multiple roles in the project. The importance of a database is not only to keep track of the work performed, but also to record as much descriptive information of the object as well as, in the next step, the process of its digitization. When was an object photographed? What are unique features that describe the object? How long did it take to complete the digitization of a single object? Who performed the digitization?

In order to accommodate this information, the database consists of 34 fields per object, which are filled during digitization and processing efforts. Information at object level is recorded as well as individual details at folio level. For example, it is not unusual for manuscript codices to have incorrect foliation numbers. A scholar numbering each folio (foliation) could sometimes skip a number or use it twice.

Table 3.2

Object level information recorded for individual images of folia

	Description	Example #1	Example #2
S/N	Serial Number according to order of digitized objects	1	2
Shelfmark	Identifier of number that includes language and number	Arabic 254	Arabic 624
Category	Object imaging difficulty: 1 not fragile, 2 some special care required, 3 fragile object, 4 not possible to be imaged prior to conservation	1	1
Language	Language of manuscript contents	Arabic	Arabic
Palimpsest?	Presence of palimpsestation in the object	No	No
Form	Manuscript form: Codex, Fragment, Scroll	Codex	Codex
Material	Object material: paper, parchment, papyrus	Paper	Paper
Date In	Date range start	1732	1601
Date Out	Date range end	1732	1700

Subject Category	Thematic category of manuscript contents	Liturgica: Services	Liturgica: Liturgy
Folia	Number of foliated pages	46	23
Fly-leaves Front	Number of front fly leaves (unnumbered pages)	0	0
Fly-eaves Back	Number of back fly leaves (unnumbered pages)	0	0
Paste Front	Down Number of detached folia from the inside of front cover	0	0
Paste Back	Down Number of detached folia from the inside of back cover	0	0
External sides	Number of external sides can be 4-6 (if either of front or back cover is missing) spine, forehead, head, tail, back cover, front cover	6	6
Imaging Start	Start date of object imaging	05/23/18	05/24/18
Imaging End	End date of object imaging	05/24/18	05/24/18
Height (mm)	Height of external dimensions	210	224
Width (mm)	Width of external dimensions	166	165
Thickness (mm)	Thickness of external dimensions	20	12
Weight (g)	Total weight of all object components	265.0	138.3
Camera Operator	Photographer assigned for object digitization	Vasilis K.	Lampros G.
System	Imaging workstation used for digitization	BC100 - 2 cam.	BC100 - 2 cam.
PPI	Special resolution of digitization measured in Pixels Per Inch of the final captured image	718	715
Lens Setup	Lens used on imaging system: 90mm or 120mm	90mm	90mm
Comments	Any comments regarding the physical condition and page numbering of the object. Missing folia, repeated page numbering, areas of damages, general instruction to Photographers on material handling of specific object	-	4AB / 11AB / 16AB

Total Images	Total images captured for specific object including covers	100	55
Session Total	Total of imaging session from all workstations	-	-
User Comments	Comments of photographer regarding observations in the content of the object or abnormalities in the naming of the digital files	-	21r = y_999
Processed?	Has the object been processed? (cropped, developed to tif files)	ok	ok
Process comments	Comments regarding digital files and metadata during object image processing phase	-	-
Metadata?	Has the object been embedded with metadata?	ok	ok
Transfer Drive	Is the object copied into transfer drives for transportation to the UCLA?	ok	ok

3.5.2 Tool 2: SLD Metadata Codex Macro

This is a tool based in Microsoft Excel, written in programming language of visual basic. Its function is to generate individual page level metadata. This is done by directly retrieving information from the Progress_Workbook database to populate the appropriate metadata fields using a Dublin Core schema. The tool generates as many lines of metadata information as pages exist in an object and checks for any abnormalities in the file-naming, as accidental repeated foliation numbers.

This tool was inspired from the work of John Stokes who used a similar approach to generate imaging shoot lists for his capturing software IWS. The physicist Grigorios Kasotakis provided support and knowhow in the initial stages of the development and for the adaptation of the tool to the SLDP needs.

The user only has to insert in the tool a manuscript's shelfmark and the embedded computer scripts will search and retrieve all relative information. The user then has to press a series of five buttons to automatically generate a metadata list for all individual

pages, save the work and export it as a .CSV file that can later be used to embed this information in all images of the object.

The programming code of the tool is divided into two modules. The first module controls all the buttons that the user operates and advances the steps. The second module is the core of the metadata generation for each page.

Module 1

```
Option Explicit
Export file to new EXCEL file
'Sub Export_codex_xlsm()
    Dim FSO
    Dim sFolder As String
    Dim ObjectName As String
    Dim MyFileName As String
    Dim CurrentWB As Workbook, TempWB As workbook
    Set CurrentWB = ActiveWorkbook
    ObjectName = Worksheets("Set_values").Cells(3, "B").Value
    sFolder = CurrentWB.Path & "\" & ObjectName
    MyFileName = CurrentWB.Path & "\" & Left(ObjectName,
Len(CurrentWB.Name) - 5) & ".xlsm"
    Application.DisplayAlerts = False
    CurrentWB.SaveAs Filename:=MyFileName,
FileFormat:=xlOpenXMLWorkbookMacroEnabled, CreateBackup:=False,
Local:=True
    Application.DisplayAlerts = True
End Sub
'Sub Save_xlsm()
Save current workBook
    ActiveWorkbook.Save
End Sub
'Sub Exit_workbook()
Exit current workBook
    ActiveWorkbook.Close
End Sub
Export to CSV file
'Sub Export_codex_CSV()
    Dim ObjectName As String
    Dim MyFileName As String
    Dim CurrentWB As Workbook, TempWB As workbook
    Set CurrentWB = ActiveWorkbook
    ActiveWorkbook.Worksheets("csv_ready").UsedRange.Copy
    ObjectName = Worksheets("Set_values").Cells(3, "B").Value
    Set TempWB = Application.Workbooks.Add(1)
    With TempWB.Sheets(1).Range("A1")
        .PasteSpecial xlPasteValues
        .PasteSpecial xlPasteFormats
    End With
    MyFileName = CurrentWB.Path & "\" & Left(ObjectName,
Len(CurrentWB.Name) - 5) & ".csv"
    Application.DisplayAlerts = False
    TempWB.SaveAs Filename:=MyFileName, FileFormat:=xlCSV,
CreateBackup:=False, Local:=True
    TempWB.Close SaveChanges:=False
    Application.DisplayAlerts = True
End Sub
```

Module 2

```
Sub codex1_button()
    Application.ScreenUpdating = False
    Application.Calculation = xlCalculationManual
    Application.EnableEvents = False
    '##### FOR INTERNAL PURPOSES ONLY #####
    ' codex1 Macro
    ' Shootlist Metadata Generator v2.5b (update 20200903)
    ' Macro created for the Sinai Digitization Project - 2018
```

```

' Created by:
' Gregory Kasotakis & Damianos Kasotakis | Early Manuscripts Electronic
Library
' Inspired by a design of:
' John Stokes | Stokes Imaging
  Sheets("CSV_ready").Select
' Establish integer and string
  Dim P As Integer, R As Integer, NP As Integer
  Dim FFL As Integer, BFL As Integer, FRG As Integer
  Dim ManNum As Integer
  Dim WeightGrams As String
  Dim DimYmm As Integer, DimXmm As Integer
  Dim DimZmm As String
  Dim ApertureValue As Integer
  Dim FPD As Integer, BPD As Integer
  Dim ManLoc As String, ManName As String, ManLang As String, Identifier
As String
  Dim Abbreviation As String, folio As String, l2r As String, CompPal As
String
  Dim Palimpsest As String, Dimmm As String, Collection As String
  Dim Form As String, MsSubstrate As String, Project As String
  Dim SubjectScheme As String
  Dim LensInfo As String, LensMake As String, LensModel As String
  Dim Contributor As String, Artist As String, Description As String
  Dim Rights As String, IPTCkeywords As String, Format As String
  Dim Comments As String, LeadZ As String, Relation As String, dcType As
String
  Dim Publisher As String, Title As String
' Set width of columns (cosmetic)
  Columns("A").ColumnWidth = 3
  Columns("A").ColumnWidth = 20
  Columns("B").ColumnWidth = 28
  Columns("C").ColumnWidth = 21
  Columns("D").ColumnWidth = 11
  Columns("E").ColumnWidth = 9
  Columns("F").ColumnWidth = 21
  Columns("G").ColumnWidth = 5
  Columns("H").ColumnWidth = 41
  Columns("I").ColumnWidth = 16
  Columns("J").ColumnWidth = 18
  Columns("K").ColumnWidth = 6
  Columns("L").ColumnWidth = 13
  Columns("M").ColumnWidth = 14
  Columns("N").ColumnWidth = 14
  Columns("O").ColumnWidth = 12
  Columns("P").ColumnWidth = 17
  Columns("Q").ColumnWidth = 30
  Columns("R").ColumnWidth = 25
  Columns("S").ColumnWidth = 10
' Define values of string and integer from specific cells or specific
values
  ManLoc = worksheets("Set_values").Cells(27, "B").Value
  ManName = worksheets("Set_values").Cells(2, "B").Value
  ManLang = worksheets("Set_values").Cells(1, "B").Value
  Abbreviation = worksheets("Set_values").Cells(3, "B").Value
  Identifier = ManLoc + " " + ManName + " | " + Abbreviation
  NP = worksheets("Set_values").Cells(4, "B").Value
  FPD = 1
  BPD = 1
  FFL = 10
  BFL = 10
  WeightGrams = worksheets("Set_values").Cells(5, "B").Value
  DimYmm = worksheets("Set_values").Cells(6, "B").Value
  DimXmm = worksheets("Set_values").Cells(7, "B").Value
  DimZmm = worksheets("Set_values").Cells(8, "B").Value
  Dimmm = DimYmm & " x " & DimXmm & " x " & DimZmm & " mm"
  Palimpsest = worksheets("Set_values").Cells(11, "B").Value
  CompPal = worksheets("Set_values").Cells(12, "B").Value
  Collection = worksheets("Set_values").Cells(9, "B").Value
  Form = worksheets("Set_values").Cells(15, "B").Value
  MsSubstrate = worksheets("Set_values").Cells(9, "B").Value
  SubjectScheme = worksheets("Set_values").Cells(23, "B").Value + " | "
+ ManLang
  LensInfo = worksheets("Set_values").Cells(24, "B").Value
  LensMake = worksheets("Set_values").Cells(25, "B").Value
  LensModel = worksheets("Set_values").Cells(13, "B").Value
  ApertureValue = worksheets("Set_values").Cells(14, "B").Value

```

```

'FRG = worksheets("Set_values").Cells(23, "B").value
Project = worksheets("Set_values").Cells(26, "B").value
dcType = worksheets("Set_values").Cells(28, "B").value
folio = worksheets("Set_values").Cells(16, "B").value
Contributor = worksheets("Set_values").Cells(28, "B").value
Artist = worksheets("Set_values").Cells(29, "B").value
Description = worksheets("Set_values").Cells(30, "B").value
Publisher = worksheets("Set_values").Cells(31, "B").value
Rights = worksheets("Set_values").Cells(32, "B").value
Format = Str(weightGrams) & " g " & "/" & Dimmm & "/" & Form & "/" &
MsSubstrate
IPTCkeywords = "Palimpsest component: " + CompPal + " | " + "Object
Palimpsest: " + Palimpsest
Comments = worksheets("Set_values").Cells(34, "B").value
Relation = Collection + " | " + ManLoc + " " + ManName

' Text of cells for the first row of CSV_ready sheet
' Important to be accurate with what EXIF-TOOL can read
' for proper metadata import.
R = 1
Cells(R, "A").value = "SNum"
Cells(R, "A").value = "SourceFile"
Cells(R, "B").value = "XMP-dc:Title"
Cells(R, "C").value = "XMP-exif:Usercomment"
Cells(R, "D").value = "LensInfo"
Cells(R, "E").value = "LensMake"
Cells(R, "F").value = "LensModel"
Cells(R, "G").value = "ApertureValue"
Cells(R, "H").value = "IPTC:Keywords"
Cells(R, "I").value = "XMP-exif:Artist"
Cells(R, "J").value = "XMP-dc:Identifier"
Cells(R, "K").value = "XMP-dc:Language"
Cells(R, "L").value = "XMP-dc:Description"
Cells(R, "M").value = "XMP-dc:Publisher"
Cells(R, "N").value = "XMP-dc:Rights"
Cells(R, "O").value = "XMP-dc:Source"
Cells(R, "P").value = "XMP-dc:Subject"
Cells(R, "Q").value = "XMP-dc:Format"
Cells(R, "R").value = "XMP-dc:Relation"
Cells(R, "S").value = "XMP-dc:Type"
' Metadata for the recto/verso folia
' and most foliation anomalies (AB) or reshoots (-2)
R = R + 1
If folio = "no" Then
    P = P + 1
    R = R + 1
End If
Next P
For P = 1 To NP
    If P < 10 Then
        LeadZ = "00"
    ElseIf (P >= 10 And P < 100) Then
        LeadZ = "0"
    ElseIf (P >= 100 And P < 1000) Then
        LeadZ = ""
    Else: LeadZ = ""
    End If
    Cells(R, "A").value = R - 1
    If folio = "yes" Then
        Cells(R, "A").value = Project & "_" & Abbreviation & "_f_" & LeadZ & P
& ".tif"
    Else
        Cells(R, "A").value = Project & "_" & Abbreviation & "_f_" & LeadZ & P
& ".tif"
    End If
    Cells(R, "B").value = ManLoc + " " + ManName + " " + LeadZ & P & "r"
    Cells(R, "C").value = Comments
    Cells(R, "D").value = LensInfo
    Cells(R, "E").value = LensMake
    Cells(R, "F").value = LensModel
    Cells(R, "G").value = ApertureValue
    Cells(R, "H").value = IPTCkeywords
    Cells(R, "I").value = Artist
    Cells(R, "J").value = Identifier
    Cells(R, "K").value = ManLang
    Cells(R, "L").value = Description
    Cells(R, "M").value = Publisher

```

```

Cells(R, "N").value = Rights
Cells(R, "O").value = ManLoc + " " + ManName
Cells(R, "P").value = SubjectScheme
Cells(R, "Q").value = Format
Cells(R, "R").value = Relation
Cells(R, "S").value = dcType
R = R + 1
If folio = "no" Then
    P = P + 1
End If
Cells(R, "A").value = R - 1
If folio = "yes" Then
    Cells(R, "A").value = Project & "_" & Abbreviation & "_f_" & LeadZ & P
    & ".tif"
Else
    Cells(R, "A").value = Project & "_" & Abbreviation & "_f_" & LeadZ & P
    & ".tif"
End If
Cells(R, "B").value = ManLoc + " " + ManName + " " + LeadZ & P & "v"
Cells(R, "C").value = Comments
Cells(R, "D").value = LensInfo
Cells(R, "E").value = LensMake
Cells(R, "F").value = LensModel
Cells(R, "G").value = ApertureValue
Cells(R, "H").value = IPTCkeywords
Cells(R, "I").value = Artist
Cells(R, "J").value = Identifier
Cells(R, "K").value = ManLang
Cells(R, "L").value = Description
Cells(R, "M").value = Publisher
Cells(R, "N").value = Rights
Cells(R, "O").value = ManLoc + " " + ManName
Cells(R, "P").value = SubjectScheme
Cells(R, "Q").value = Format
Cells(R, "R").value = Relation
Cells(R, "S").value = dcType
R = R + 1
If folio = "no" Then
    P = P + 1
    R = R + 1
End If
'Switch to Set_values worksheet
Worksheets("Set_values").Activate
Application.Calculation = xlCalculationAutomatic
Application.EnableEvents = True
End Sub
Sub search_codex1()
Application.ScreenUpdating = False
Application.Calculation = xlCalculationManual
Application.EnableEvents = False
Worksheets("Set_values").Rows("62").Copy
Worksheets("Set_values").Rows("18").PasteSpecial Paste:=xlPasteValues
Application.Calculation = xlCalculationAutomatic
Application.EnableEvents = True
End Sub
Sub insert_codex1()
Application.ScreenUpdating = False
Application.Calculation = xlCalculationManual
Application.EnableEvents = False
Worksheets("Set_values").Rows("18").Copy
Worksheets("csv_ready").Range("A2").End(xlDown).Offset(1, 0).PasteSpecial
Paste:=xlPasteValues

Application.Calculation = xlCalculationAutomatic
Application.EnableEvents = True
End Sub

```

The excel spreadsheet presents for verification all the information pulled automatically from the spreadsheet “Progress_Workbook”. To simplify the user interface, distinct buttons are placed on the right side performing specific actions. (Figure 3.9)

3.5.3 Tool 3: Counting Script

This is a tool written in the programming language of Microsoft PowerShell. Its main function is to be used right after the digitization of a single manuscript. It accurately checks how many pictures were captured, and how many folia exist in the manuscript. Secondly it can check if a single page was not imaged or if a page was imaged but with a duplicate folio number.

This tool is crucial for informing the camera operator if he accidentally skipped a page and did not image it, or if two files exist with the same folio number. This could indicate a mistake in the file naming of specific folia/images.

The operators can run the script from any Microsoft Windows running terminal connected to the local network and check any folder of a digitized manuscripts. Upon execution the user is asked to select a folder of a manuscript and the following procedures happen automatically.

The script finds and then deletes any folder named *Trash* in order to avoid any problems in the counting of the files.

```
Get-ChildItem * -attributes D -Recurse -include "Trash" | Remove-Item
```

Right after it recursively searches and counts all files ending with *.IIQ extension and filters them to include only the ones that include in the filename the suffix *sld_*. In this way the counting will only include manuscript images and not calibration shots that do not include this suffix.

```
$shots = (Get-ChildItem -Path .* -rec -include *.IIQ -filter *sld_*.count
```

A new search filters and counts all files that include in the filename this sequence of characters “_f_”, which is part of the naming schema only for pictures of folia.

```
Get-ChildItem -Path .* -rec -include *.IIQ -filter *_f_* | where  
{$_ .FullName -like "*\Capture\*"} | Group-Object -NoElement -Property  
Directory
```

Afterwards, the script searches all files to check if all numbers of a sequence exist in a logical order (1-n). All images of folia include a three-digit number between the *_f_*

part and the file type *.IIQ. The script locates the final three-digit number of the last page (for example 203) and then verifies that all numbers from 1 to 203 are present. In the case a number is not found, or a duplicate number is found, an error message appears, listing the specific potential problematic images by filename.

```

Get-ChildItem -Path '.\*\*' -include capture -rec -Directory |
    ForEach-Object {
        $Folder = $_.FullName
        $LastFile = Get-ChildItem $Folder -File -Filter '*_f_*' | Sort-
Object -Property BaseName | Select-Object -Last 1
        $filenamestart = ($LastFile.BaseName -split '_f_')[0]
        $filenameend = ($LastFile.BaseName -split '_f_')[1]

        $LastNumber = (($LastFile.BaseName -split '_f_')[1] -split '[a-
z]*[rv]$')[0]
        $fileendchars = $filenameend.SubString($LastNumber.Length)
        1..$LastNumber |
            ForEach-Object {
                $duplicatefilecheck = Join-Path -Path $Folder -ChildPath
("_{1}_f_{0:000}*.IIQ" -f $_,$filenamestart)
                if ($fileendchars -match ".{2}") {
                    $filetocheck = Join-Path -Path $Folder -ChildPath
("_{2}_f_{0:000}{1}.IIQ" -f $_,$fileendchars.SubString(1),$filenamestart)
                } else {
                    $filetocheck = Join-Path -Path $Folder -ChildPath
("_{2}_f_{0:000}{1}.IIQ" -f $_,$fileendchars,$filenamestart)
                }
            }
        $countfiles = Get-ChildItem $duplicatefilecheck |
Measure-Object | %{$_.Count}

        if( $countfiles -eq 0){
            write-host "$filetocheck" -ForegroundColor red
        } elseif($countfiles -gt 1){
            write-host "$filetocheck" -ForegroundColor blue
        }
    }
}

```

The three functions listed above are all presented to the user by previewing the total number of images captured for a manuscript, the number of folia, and an error in the foliation if present. (Figure 3.10)

Below is the script in its entirety:

```

$erroractionpreference = "silentlycontinue"
write-host
"=====
=====
write-host " "
write-host " How to use this script:" -ForegroundColor green
write-host " -----" -ForegroundColor green
write-host " Total shots are External Sides + Recto/Verso + other MS
components."
write-host " Please keep one of the two numbers in second set to get
number of folia."
write-host " "
write-host
"=====
=====
write-host " "
get-childitem * -attributes D -recurse -include "Trash" | remove-item
$shots = (get-childitem -path .\* -rec -include *.IIQ -filter
*sld_*.count)
write-host " "
write-host " "

```

```

Write-Host "Number of total shots: $shots" -ForegroundColor Green
Write-Host " "
Write-Host "Numbers below are folia. Keep only one!"
Get-ChildItem -Path .* -rec -include *.IIQ -filter *_f_* | where
{$_ .FullName -like "*\Capture\*" } | Group-Object -NoElement -Property
Directory
Write-Host " "
Write-Host " "
Write-Host "Missing in Red and Duplicate in Blue folia: "
Get-ChildItem -Path '.\*\' -include Capture -rec -Directory |
    ForEach-Object {
        $Folder = $_.FullName
        $LastFile = Get-ChildItem $Folder -File -Filter '*_f_*' | Sort-
Object -Property BaseName | Select-Object -Last 1
        $filenamestart = ($LastFile.BaseName -split '_f_')[0]
        $filenameend = ($LastFile.BaseName -split '_f_')[1]

        $LastNumber = (($LastFile.BaseName -split '_f_')[1] -split '[a-
z]*[rv]$')[0]
        $fileendchars = $filenameend.SubString($LastNumber.Length)
        1..$LastNumber |
            ForEach-Object {
                $duplicatefilecheck = Join-Path -Path $Folder -ChildPath
("_{1}_f_{0:000}*.IIQ" -f $_,$filenamestart)
                if ($fileendchars -match ".{2}") {
                    $filetocheck = Join-Path -Path $Folder -ChildPath
("_{2}_f_{0:000}{1}.IIQ" -f $_,$fileendchars.SubString(1),$filenamestart)
                } else {
                    $filetocheck = Join-Path -Path $Folder -ChildPath
("_{2}_f_{0:000}{1}.IIQ" -f $_,$fileendchars,$filenamestart)
                }
                $countfiles = Get-ChildItem $duplicatefilecheck |
Measure-Object | %{$_.Count}

                if( $CountFiles -eq 0){

                    write-host "$filetocheck" -ForegroundColor red

                } elseif($CountFiles -gt 1){
                    write-host "$filetocheck" -ForegroundColor blue
                }
            }
    }
Write-Host " "
Write-Host " "
Read-Host -Prompt "Press Enter to exit"

```

This script is transformed to an EXE (Executable Program, *.EXE) with software “PS1 to EXE” which makes the procedure more user-friendly as it runs with a single click and does not require any command line input. The user can execute the program, select through a menu the folder of a manuscript to check, and click RUN. The results are presented in a matter of seconds.

3.6 Data Transportation and Long-Term Storage

Data captured through digital sensors during the digitization sessions are the equivalent raw material of analog film. Like analog forms of photography, for example glass plates, microfilms, and films, digital data need to be curated and archived. Archived data need to be safeguarded and stored under specific conditions that will

maximize their lifespan. For the SLDP I designed a data workflow procedure that ensures protection against data loss from the first steps of the data production. Each digitization station is linked to a local storage unit that directly stores all captured data as they are captured from the camera. This local storage unit has three features: a) fast data accessibility, b) enough space to accommodate the data of two or three imaging sessions, c) accidental data loss prevention. In order to meet the above criteria, the RAID 5 technology is utilized by connecting five hard drives together and programming them to work as one device. In RAID 5 data are segmented and parity information is distributed between the hard drives. Any of the five drives can fail without data loss. But it would need to be replaced as soon as possible in order to avoid complete data failure in case a second drive fails.

For the centralized archiving of data, a dedicated storage server is installed inside the imaging room. The data server can support up to 45 Hard Disk Drives (HDD) connected internally in it. Running on open-source Linux based operating system, it assures the stability and minimum requirement of resources to operate. The HDD located inside the storage server are formatted in EXT4 and linked in groups of ten, configured to operate as ZFS pools. ZFS is a technology that allows a number of HDD to be programmed and operate as one unit, so that their collective capacity can be summed. EXT4 file format is native to the Linux ecosystem and is proven to be a stable and fast way of mapping the data in an HDD. The groups of 10 drives are programmed to fragment and distribute data among them. The group has a tolerance of up to two failed drives not affecting the integrity of the total data stored.

Two high-capacity data storage servers are installed for the SLDP so far: one in the Sinai Monastery, and a “clone” of it in Athens (Greece). The presence of a third copy of the data in UCLA (U.S.A.) ensures the absolute security and longevity of the digitized manuscript pages, since the same data are present in three distinctly different geographical locations.

While moving data from one device to another there is a small risk of data being corrupted. In an environment where thousands of data files are being transferred it is impossible to ensure their integrity using manual verification. For this reason, I developed procedures that would automate the check of data integrity. The safest method for data transfer is to create a digital signature of each file (checksum or

cryptographic hash) before moving it from one location to another. When the file arrives to the next location, an automated script can check the signatures of the newly created files and cross-reference them with the ones created from the source location before the move (checksum verification or hash check). The fastest method of generating these checksums is the MD5 algorithm.

3.7 Image Processing and Quality Assurance

While capturing photons and translating them to electrons is the first step of digitization process, this raw form of digital image – equivalent to the negatives of analog film – is not ready for publication. This file is fine-tuned in terms of exposure and brightness. Exposure is measured by targets that are manufactured under specifications and should provide the same readouts when measured through an imaging software. Through the same targets, white balance of the captured scene is calculated, which is affected by the thermal tone of the lights that illuminate the scene.

The accuracy of the digitized color compared to the physical object is determined by the calibration procedures. A calibrated color target with multiple color patches (X-rite Colorchecker SG) is photographed before imaging a manuscript. The picture of the color target is imported into a calibration software (BasIColor) that reads each of the individual color patches and compares it with the specifications of the manufacturer. The calibration software takes into consideration the thermal tone of the lights and in turn produces a corrections file (ICC, International Color Consortium) for the values that deviate. This ICC file is imported into the specific camera that is calibrated and used to present accurate color of the physical object.

All images must be sufficiently sharp so that all elements of the page are clear to the viewer. To achieve this, a combination of tools is used. A focusing target is placed on the surface of the object in order to seek optimal sharpness with the assistance of software utilities embedded into the capturing software. The software utility measures on real time the difference in contrast of what the digital camera “sees” as the camera operator shifts the lens closer or farther away from the sensor. When the software detects highest levels of contrast it notifies the user for the optimal sharpness of the digital picture.

The digitized image that has correct exposure, white balance, accurate color, and optimal sharpness is ready to be cropped, adjusted by rotation (if needed) and exported into an archival format image file (TIFF).

For cropping large volumes of pages, I developed a semi-automated method. The user forms a cropping box of 0.5 inches around the edges of all four sides of a page, copies the coordinates and dimensions of the box and pastes it into the next image through a keyboard shortcut. If needed, the user can move around the box until the edges meet the 0.5 inches criteria from all four sides. At the same time, if needed, the user can rotate the image so that the spine remains always vertical, at 90 degrees. Finally, the cropped and properly rotated page is exported into TIFF format.

3.8 Metadata

Metadata is information that identify a digital image file. They are divided into technical and descriptive information. Technical metadata provide information for the technology that was used to capture the image (camera model, lens, exposure time, etc.). While descriptive metadata identify the object and describe both the physical characteristics and the content of the page (dimensions, content category, etc.), descriptive metadata are governed by international standards. Following the Dublin Core (DC) standards, all image files are embedded into the Exif TIFF headers (Exchangeable image file format, digital notes included into the image file) using XMP protocol (Extensible Metadata Platform).

Table 3.3

Metadata recorded, example, and description

	Location	Technical / Descriptive	Stage of embedment	Example	Description
Make	Exif	Technical	On Capture	PhaseOne	Digital back manufacturer
Model	Exif	Technical	On Capture	IQ3 100MP	Digital back model
Orientation	Exif	Technical	On Capture	Horizontal	Orientation of captured image

XResolution	Exif	Technical	On Capture	1095	Vertical Pixels Per Inch
YResolution	Exif	Technical	On Capture	1095	Horizontal Pixels Per Inch
Software	Exif	Technical	On Capture	Capture One 10 Macintosh	Capturing or editing software (CaptureOne or Photoshop)
ExposureTime	Exif	Technical	On Capture	1/6	Exposure Time of imaging sensor to light
ISO	Exif	Technical	On Capture	100	Light sensitivity of imaging sensor. Constant at 100 ISO
DateTimeOriginal	Exif	Technical	On Capture	2018:06:01 12:17:32	Date/time of image capture
CreateDate	Exif	Technical	On Capture	2018:06:01 12:17:32	Date/time of file creation
ShutterSpeedValue	Exif	Technical	On Capture	1/6	Exposure Time of imaging sensor to light
ApertureValue	Exif	Technical	Post Capture	11.0	Aperture opening of shutter
SerialNumber	Exif	Technical	On Capture	IG011399	Serial number of capturing digital sensor
LensMake	Exif	Technical	Post Capture	Schneider	Lens manufacturer
LensModel	Exif	Technical	Post Capture	APO-DIGITAR 120/5.6 SES	Lens specific model
dc-Description	XMP-dc	Descriptive	Post Capture	Statement of responsibility: Imaging performed under the auspices of His Eminence Archbishop Damianos and The Holy Council. Father Justin Sinaites Librarian Early Manuscripts Electronic Library.	Statement of responsibility

Phelps Michael B.
Project Director.
Kasotakis
Damianos. Imaging
Director

dc-Format	XMP-dc	Descriptive	Post Capture	344 g / 160 x 114 x 39 cm / Codex / Paper	Weight of Object / External dimensions of Object / Format of Object / substrate
dc-Identifier	XMP-dc	Descriptive	Post Capture	Sinai Arabic 57 arb0057	Shelfmark of object / Abbreviation of object in the filename
dc-Language	XMP-dc	Descriptive	Post Capture	Arabic	Language of object
dc-Publisher	XMP-dc	Descriptive	Post Capture	The Holy Monastery of Saint Catherine Sinai Egypt Early Manuscripts Electronic Library University of California Los Angeles The Sinai Library Digitization Project Collaboration	Project publishers/partners
dc-Relation	XMP-dc	Descriptive	Post Capture	Old Collection Sinai Arabic 57	Object collection (New Finds or Old Collection)
dc-Rights	XMP-dc	Descriptive	Post Capture	Contact the Monastery of St. Catherine's of the Sinai Metadata: Unless otherwise indicated all metadata associated with this manuscript is copyright the authors and	Copyright information

released under
Creative Commons
Attribution 4.0
International
License.

dc-Source	XMP-dc	Descriptive	Post Capture	Sinai Arabic 57	Shelfmark of object
dc-Subject	XMP-dc	Descriptive	Post Capture	Manuscripts Arabic	Subject category: Manuscripts (Printed Books/Manuscripts/etc.) / Language Category
dc-Title	XMP-dc	Descriptive	Post Capture	Sinai Arabic 57 Spine	Description of Specific Image from inside the object: Identifier (Sinai Arabic 57) and description Spine/Folio/Cover/etc.
dc-Type	XMP-dc	Descriptive	Post Capture	Digital Image	Type of image
Keywords	IPTC	Descriptive	Post Capture	Palimpsest component: no Object Palimpsest: no	Palimpsestation presence: component= is specific folio palimpsest? (Yes/No) Object=Does the object contain even one palimpsest component? (Yes/No)

The above metadata are generated automatically for each page of an object into a CSV file (Coma Separated Values file). Using the following Exiftool command, metadata are embedded into the TIFF headers of each object.

Table 3.4

Metadata embedment code and description of its elements

Sample code	Description
<code>exiftool -csv=arabic_0014.csv .</code>	Exiftool calls the program

-csv= notifies the program to expect a CSV file
Arabic_0014.csv is the filename of the CSV
. (space and dot) runs the script inside selected
folder

Part of the descriptive metadata of an object is the filename of the digitized images. For the SLDP it was decided from the start to follow a filename approach that could be human readable opposed to random sequence numbers generated by the capturing camera.

Handwritten codices did not have numbers on each page as modern books. It was only starting two hundred years ago (19th-century arrival of western scholars to the Sinai, Chapter 1), that scholars and librarians numerated – or more accurately: foliated – the objects. Manuscripts are counted by folia rather than sides of pages. Each folio carries a small handwritten number on the top or bottom edges. Folia are characterized by front side (recto) and a back side (verso). As described above, they have different qualities.

The SLDP image filename schema is composed by four parts. Firstly, the description of the project, then the bookshelf of the object, then the category of image (covers, folia, pastedowns, or flyleaves), and finally the number and side of the folio or number of cover side, flyleaf. The following example: `sld_grk0023_f_53r` can be read as: Sinai Library Digitization (`sld_`), Greek 23 (`_grk0023_`), group of folia(`_f_`) folio 53 recto (`_53r`).

Table 3.5

File naming schema of manuscript contents

Filename	Description
<code>sld_grk0023_a_1</code>	(front board outside)
<code>sld_grk0023_a_1a</code>	(front board outside variant with flap)
<code>sld_grk0023_a_1b</code>	(front board outside variant)
<code>sld_grk0023_b_000</code>	(front board inside)
<code>sld_grk0023_b_000a</code>	(front board inside variant)
<code>sld_grk0023_b_000b</code>	(front board inside variant)

sld_grk0023_b_000r	(pastedown, if unnumbered)
sld_grk0023_b_000v	(pastedown, if unnumbered)
sld_grk0023_b_001r	(flyleaf 1r)
sld_grk0023_b_001v	(flyleaf 1v)
sld_grk0023_b_002r	(flyleaf 2r)
sld_grk0023_b_002v	(flyleaf 2v)
sld_grk0023_f_001r	
sld_grk0023_f_001v	
sld_grk0023_f_002ar	(2 folia with same numeration)
sld_grk0023_f_002av	(2 folia with same numeration)
sld_grk0023_f_002br	(2 folia with same numeration)
sld_grk0023_f_002bv	(2 folias with same numeration)
sld_grk0023_f_004r	
sld_grk0023_f_004v	
<i>sld_grk0023_f_005_sr</i>	(stub recto between folio 4 and 5)
<i>sld_grk0023_f_005_sv</i>	(stub verso between folio 4 and 5)
sld_grk0023_f_005r	
<i>sld_grk0023_f_005r-2</i>	(re-shoot that we keep)
sld_grk0023_f_005v	
sld_grk0023_y_001r	(flyleaf 1r)
sld_grk0023_y_001v	(flyleaf 1v)
sld_grk0023_y_002r	(flyleaf 2r)
sld_grk0023_y_002v	(flyleaf 2v)
sld_grk0023_y_998r	(pastedown, if unnumbered)
sld_grk0023_y_998v	(pastedown, if unnumbered)
sld_grk0023_y_999	(back board inside)
<i>sld_grk0023_y_999a</i>	(back board inside variant with flap)
<i>sld_grk0023_y_999b</i>	(back board inside variant)
sld_grk0023_z_1	(back board outside)
<i>sld_grk0023_z_1a</i>	(back board outside variant)

<i>sld_grk0023_z_1b</i>	(back board outside variant)
<i>sld_grk0023_z_2</i>	(spine)
<i>sld_grk0023_z_3</i>	(fore edge)
<i>sld_grk0023_z_3a</i>	(fore edge variant with flap)
<i>sld_grk0023_z_4</i>	(head)
<i>sld_grk0023_z_5</i>	(tail)
<i>sld_grk0023_z_999</i>	(fragments that contain text but are foreign objects to the manuscript, for more fragments count them and use numbers from 990 to 999)

Since manuscripts were foliated with handwritten numbers by users, numerous mistakes are encountered in the digitization process, most commonly skipping or repeating a foliation number. When a number is missing, the operator alters the file naming and skips one folio number from the capturing software counter. In cases where the number is repeated once, the operator images both affected folia with the same folio number but adds a suffix of A and B on each folio depending on the order of appearance. More severe cases, in which not just one, but a series of numbers is repeated, appear infrequently. In such cases it is not helpful to resolve the foliation abnormality with added letters, rather the following schema is used: in the example below, three folia from 254 to 256 are repeated twice. Since number 257 was expected after the first occurrence of the numbers, the number that is expected (257) is recorded first and then the repeating number of the second set of folia. In this way the foliation abnormality is recorded and understandable in a descriptive manner, but a computer algorithm can also detect the new order of files and sort them in the correct alphanumerical order.

Table 3.6

File naming schema of solution for folia abnormalities

Filename	Description
<i>sld_arb0057_f_253r</i>	
<i>sld_arb0057_f_253v</i>	
<i>sld_arb0057_f_254r</i>	
<i>sld_arb0057_f_254v</i>	

sld_arb0057_f_255r	
sld_arb0057_f_255v	
sld_arb0057_f_256r	
sld_arb0057_f_256v	Normal foliation, next should be folio 257
<i>sld_arb0057_f_257_254r</i>	Folio 254 repeats where 257 is expected from last folio
<i>sld_arb0057_f_257_254v</i>	Folio 254 repeats
<i>sld_arb0057_f_257_255r</i>	Folio 255 repeats
<i>sld_arb0057_f_257_255v</i>	Folio 255 repeats
<i>sld_arb0057_f_257_256r</i>	Folio 256 repeats
<i>sld_arb0057_f_257_256v</i>	Folio 256 repeats
sld_arb0057_f_257r	Foliation returns to normal
sld_arb0057_f_257v	

3.9 Online Publication

Once all of these steps have been completed, a copy of all images ready for publication is sent and stored by the University of California in Los Angeles. As in the Sinai Palimpsests Project, UCLA has a double role. To safeguard a cold archive of all data in their original format (TIFF) and to publish online a set of images that can be accessible for free by all people interested.

To this end UCLA converts all images into JPG 2000 format. This format is able to keep high resolution standards in a compressed way that reduces the overall file size for easier for online publication. The new files are segmented into fragments under different magnifications.

Using the embedded metadata and information collected from the onsite database of the Progress_Workbook (described above), UCLA generates an IIIF manifest and generates a unique and permanent identifier for each image that can locate the specific object through the internet search from other online digitized collections.

Following the standards of the SPP all images are open access at no cost after a free registration. If an image is needed for publication the interested person must seek permission from Saint Catherine's Monastery.

3.10 Conclusions

The Sinai Library Digitization Project (SLDP) is certainly not the first photographic approach of manuscripts in the Sinai Library (Chapter 1), but is one of the most important. Building on lessons learned from past experiences of other expeditions and projects, the SLDP created an environment where the safety of the objects is the first and most important priority. The scope of the project is unique by nature as it is the first approach to the Library for all of its manuscripts and not just selective groups or “celebrity objects” (famous manuscripts that have attracted the attention of scholars as Sinai Syriac 30 and Codex Sinaiticus). The challenges in this task of preservation through photography are still not that different in the 21st century, as electricity is not stable, the location is remote and not easily accessible, and the objects are uniquely fragile. But the scholarly interest and the importance of the Sinai manuscripts is still relevant as it was in the last centuries, when explorers would travel by camels for days through the Sinai desert, in order to get a glimpse of the treasured manuscripts.

The SLDP installed four sophisticated digitization stations in the 6th century Monastery, along with supporting equipment and high-capacity storage servers. As director of imaging for the project I designed and implemented efficient and safe workflow procedures overcoming mechanical, electrical, software, and metadata related challenges. The result is a unique photography project that aims to publish on the internet 4500 manuscripts (or about 1.5 million pages), providing to researchers and any interested person, not only high-resolution images but also accurate descriptive and technical information in the form of metadata.

3.11 Figures of Chapter 3

Figure 3.1

Floor plan of modern digitization room at Saint Catherine's

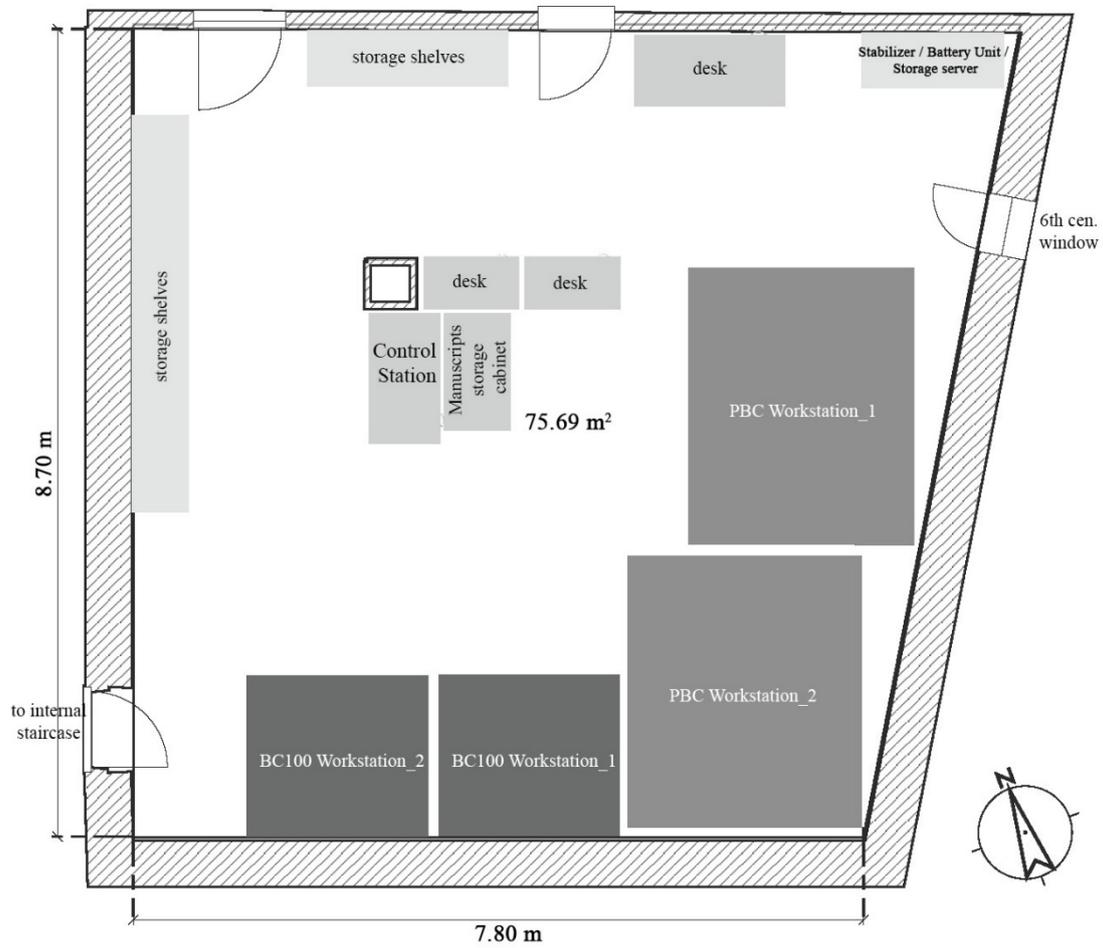


Figure 3.2

Electricity and network diagram of digitization room

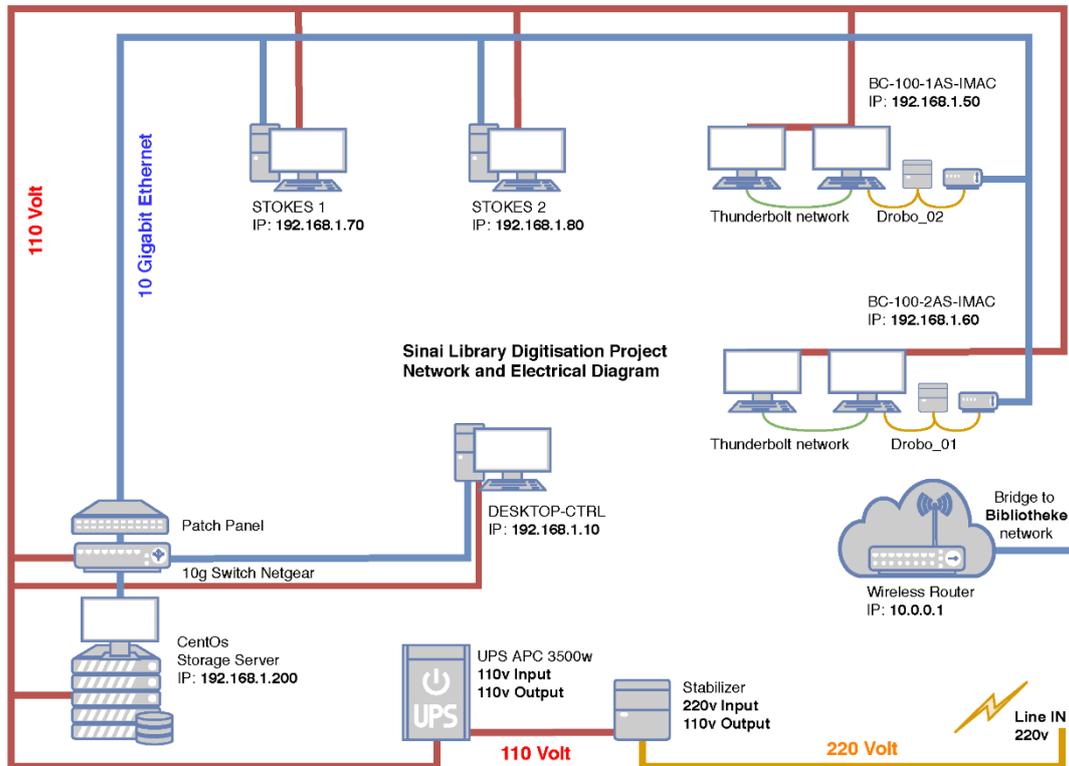


Figure 3.3

Camera operator adjusting -V- shaped book cradle on the BC100 imaging workstation



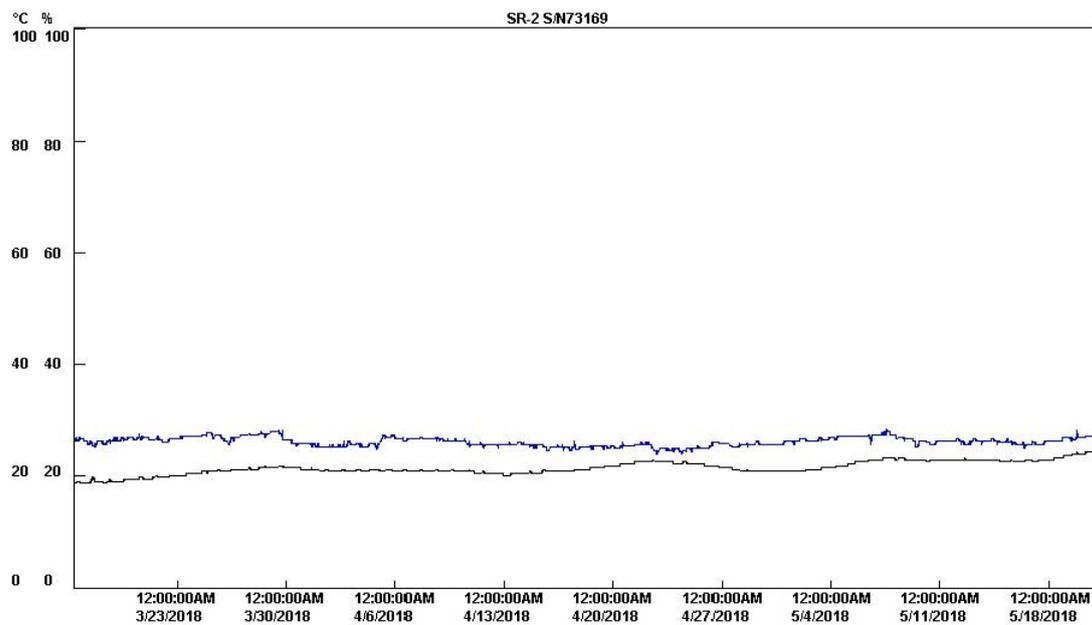
Figure 3.4

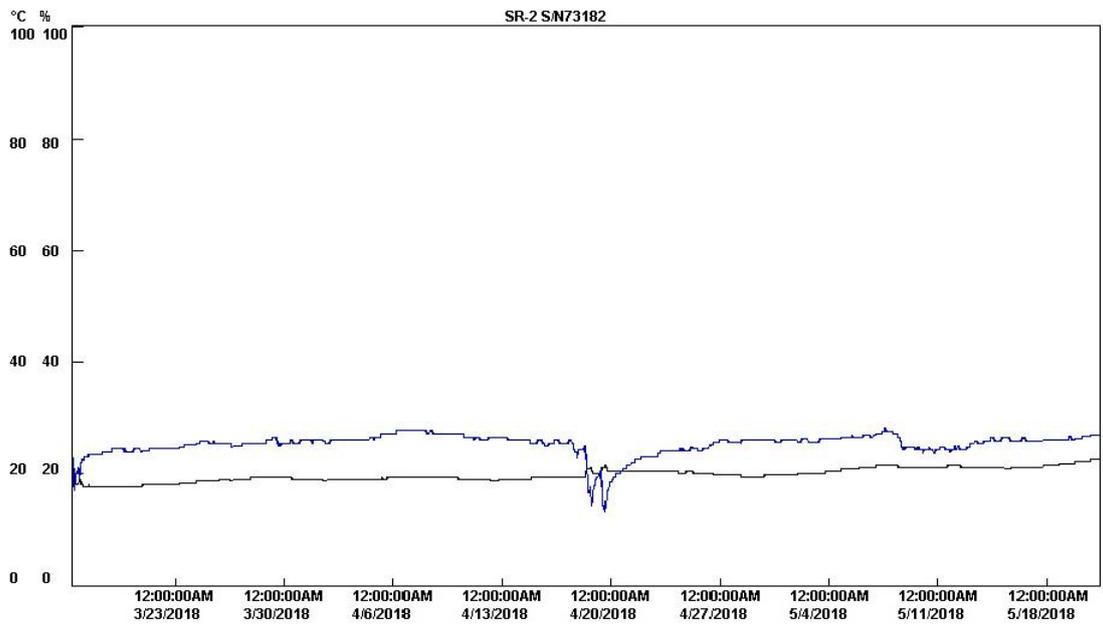
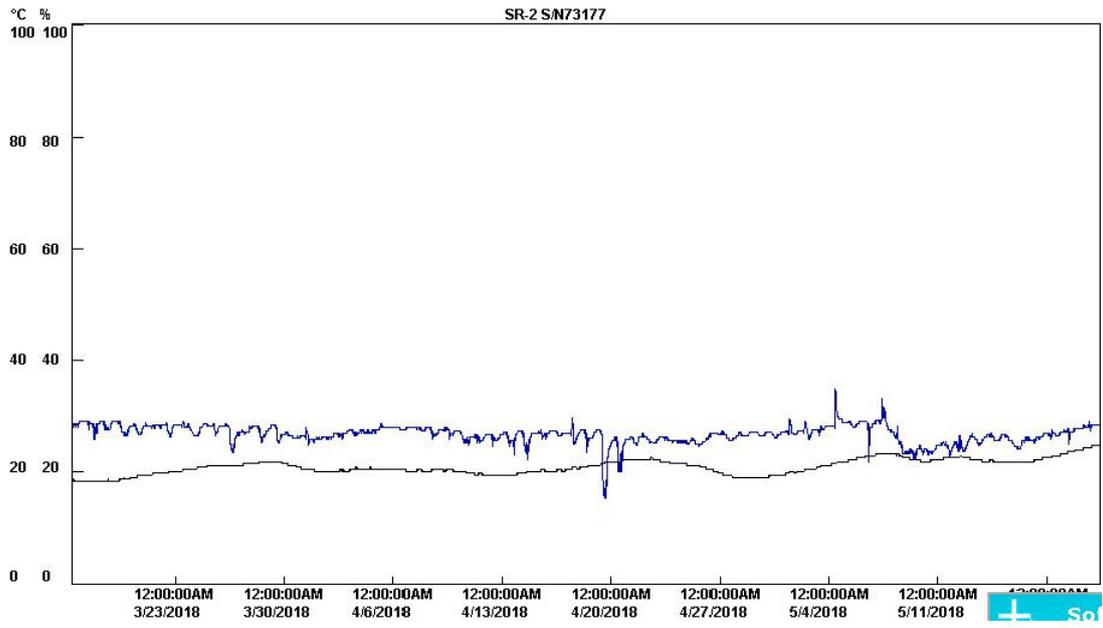
Camera operator verifying captured image on the Stokes Preservation Book cradle

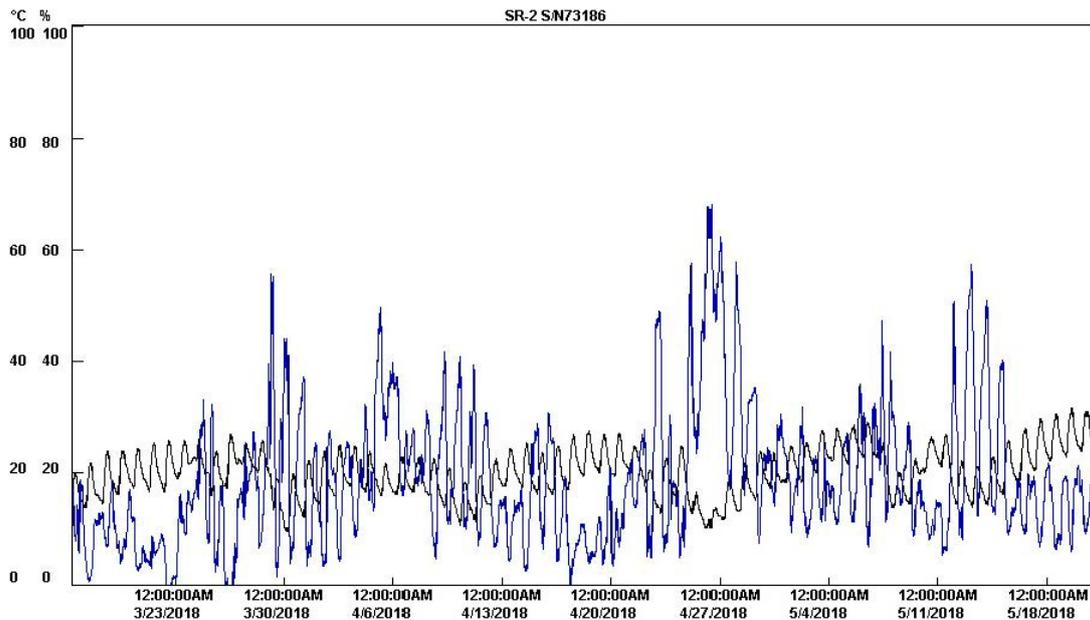


Figure 3.5

Graphs of temperature and relative humidity in manuscripts storeroom and digitization room







Note. Values of Temperature and Relative Humidity in the Manuscript Storage room, the digitization room. Recorded between 16/3/2018-22/5/2018, (1st image) graph of Archive, (2nd image) graph of Manuscripts storage room, (3rd image) graph of Outside, (4th image) graph of Photography room

Figure 3.6

Statistics of manuscripts categories based on fragility of the object

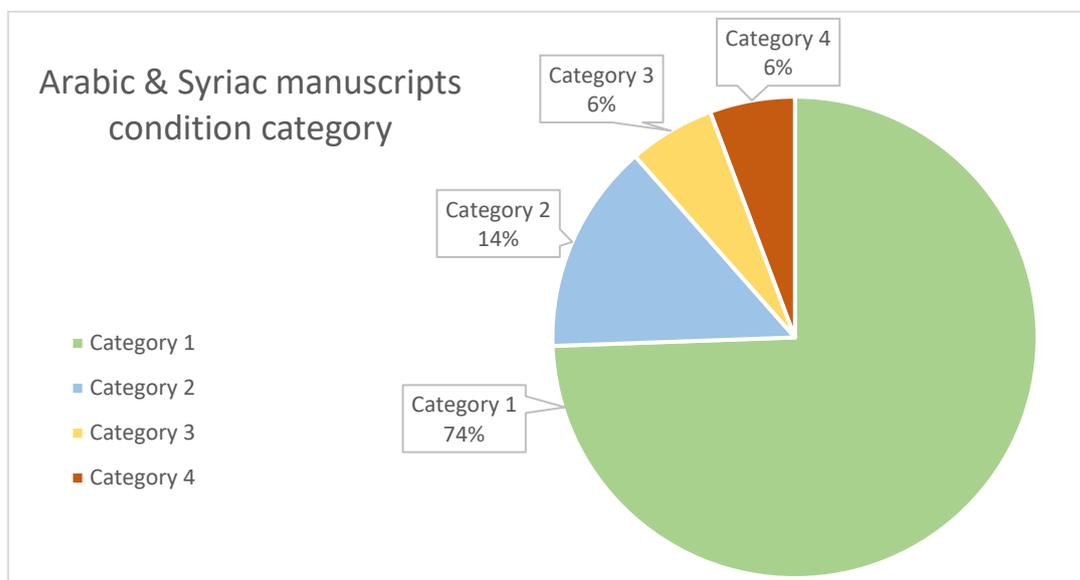


Figure 3.7

Workflow diagram of all steps from physical object to digital deliverable product

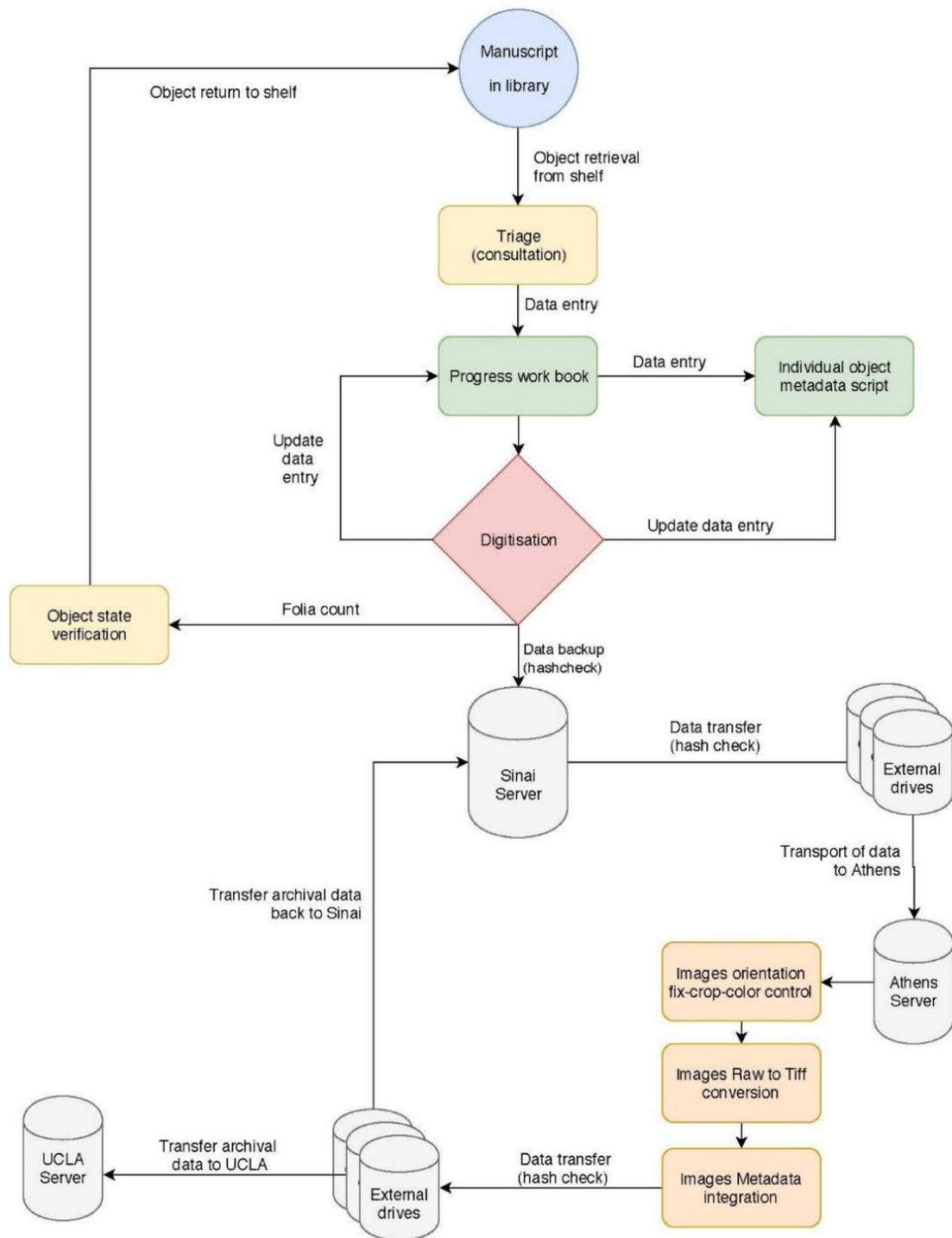


Figure 3.8

Manuscript resting on a -V- cradle of the BC100 imaging system



Note. Glass platen that flattens pages of manuscript is removed and replaced by EMEL manufactured aluminum frame

Figure 3.9

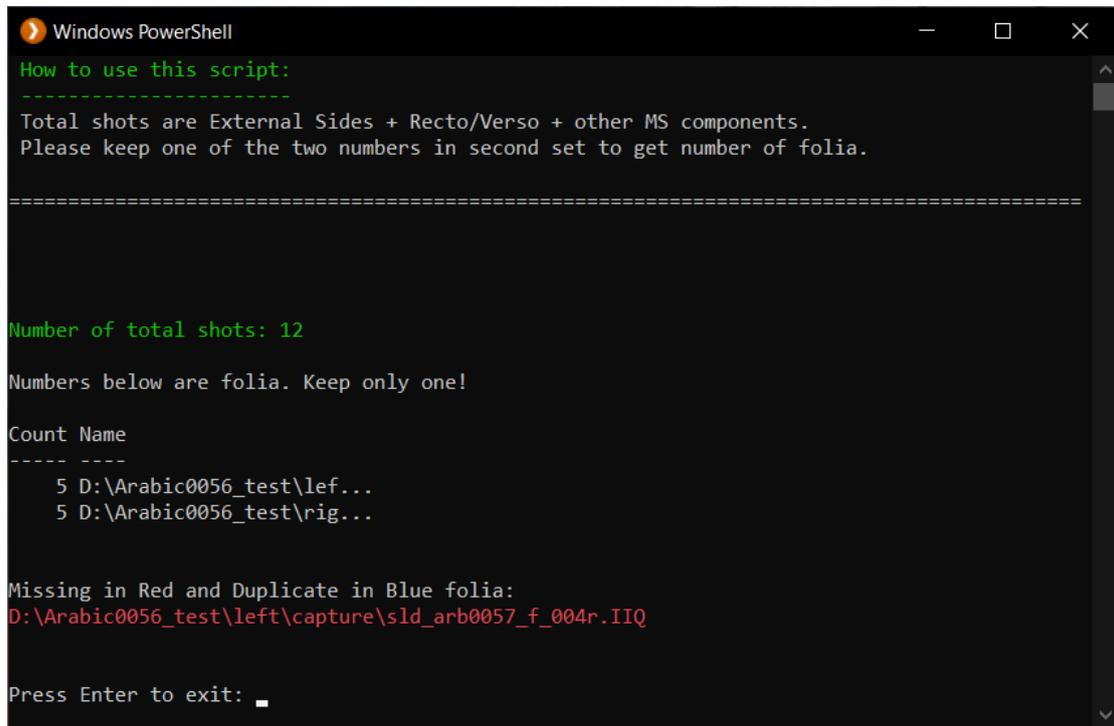
User interface of SLD metadata codex macro

A		B		C		D		E		F		G		H	
1	Language	Arabic				Sinai Library Digitization Project								1. Save As new EXCEL	
2	Manuscript name	Arabic 100				Version: Shootlist Metadata Generator 25b								2. Generate shot-list	
3	Abbreviation	arb0100				Warning: FOR INTERNAL PURPOSES ONLY									
4	Folia	210				PLEASE DO NOT CIRCULATE OR CITE WITHOUT PERMISSION									
5	Weight (g)	1054.5				Instructions: Type Manuscript name in cell B2									
6	(Height in mm) H	260				Example of Stubs format: slid_grk0023_f_004v								3. Save	
7	(Width in mm) W	180				slid_grk0023_f_005_sr / Sinai Greek 23 005 Stub Recto									
8	(Thickness in mm) T	52				slid_grk0023_f_005_sv / Sinai Greek 23 005 Stub Verso								4. Export to .CSV	
9	XMP-dc:Format MS Substrate	Paper				slid_grk0023_f_005r								5. Exit	
10	XMP-dc:Relaction Collection (Old/NF)	Old Collection				PPI: 620									
11	Palimpsest (yes/no)	No				Comments: Folio 1 split / 19AB / rodent damage on foredge									
12	Component palimpsest (yes/no)	No													
13	LensModel	APO-DIGITAR 90/4.8 SES													
14	ApertureValue	11													
15	XMP-dc:Format Form	Codex				Search shot: <input type="text" value="f_003r"/>									
16	Foliation	yes													
17	SourceFile	XMP-dc:Title		XMP-exif:Usercomment		LensInfo		LensMake		LensModel		ApertureValue		IPTC:Keywords	
18	slid_arb0100_f_003r.tif	Sinai Arabic 100 003r		0 APO-DIGITA		Schneider		APO-DIGITAR 90/4.8 SES		11		Palimpsest component: no		C	

Note. Fields are automatically populated from the progress workbook database

Figure 3.10

Counting script results interface



```
Windows PowerShell
How to use this script:
-----
Total shots are External Sides + Recto/Verso + other MS components.
Please keep one of the two numbers in second set to get number of folia.

=====

Number of total shots: 12

Numbers below are folia. Keep only one!

Count Name
-----
    5 D:\Arabic0056_test\lef...
    5 D:\Arabic0056_test\rig...

Missing in Red and Duplicate in Blue folia:
D:\Arabic0056_test\left\capture\sld_arb0057_f_004r.IIQ

Press Enter to exit: _
```

Note. Total Number of shots: 12. Five folia present on each side (recto-verso). One error message of missing page four recto (4r).

4. An Unknown Glass Plates Collection of the Sinai Monastery

Glass plate photography is a type of image capture technology used in the 19th and 20th century. The chemical photosensitive emulsion is coated upon the glass plates, which provide a stable surface (Kokla, 2019; Kokla & Tselikas, 2015).³⁰ A small collection of glass plates featuring mainly manuscripts but also images of people, buildings, and other objects survives in the Monastery of Saint Catherine today.

Images from the Monastery on glass plates also survive in other collections, such as the U.S. Library of Congress, the Vatican Library, the Bibliothèque de Genève, and elsewhere (Curtis & Alexander, 2004; Rossetto, 2019, p. 38).³¹ The Sinai collection, discovered in the 1990s, contains images that can help us travel back in time and observe activities of the monks and the Bedouins working alongside them in tasks such as grain weighing, painting of Easter eggs (Figure 4.1), and even the detailed documentation and progression of the construction of the concrete building that was erected between 1930 and 1942, within which the modern Monastery Library is housed today.

The collection had been totally forgotten and had never been stored properly – glass can easily break and the photosensitive emulsion is by nature not enduring. The emulsion can easily deteriorate, but the dry Sinai desert climate protected most of the plates in the same manner as the manuscripts and other treasures of the Monastery.

4.1 Approach to the Collection

By investigating the archives of the Monastery and by interviewing monks, former-monks, and affiliated personnel, I was able to collect the following information on the origin of the collection. The glass plates stored in unsuitable carton boxes, were discovered in the early 1990s by German archaeologist Peter Grossman from the Deutsches Archäologisches Institut - Abteilung Kairo. While inspecting the internal side walls of the “Panagia” chapel, located inside the tower at the center of the

³⁰ Vasiliki Kokla, professor at the University of West Attica | TEIATH Department of Antiquities and Works of Art Conservation, helped by giving valuable feedback and references to bibliography.

³¹ Approximately 1800 photographs of the Schmidt and Moritz expedition (1914) are located in the Vatican Library.

Monastery, Grossman noted an irregularity on one of the walls (Koufopoulos & Myriantheos-Koufopoulou, 2017; Manafis, 1990, pp. 29–39). By further investigation and with the help of Father Daniel, who at the time was Skevofilax (a monk charged with care of the church, the sacristy, and their contents), Grossman found a crack into the wall, which could be enlarged: the wall was opened and a small forgotten side storage room was discovered behind it. In it, Grossman and Father Daniel found a leather case with a glass plate photographic camera and some accessories, a tripod, as well as the boxes of glass plate negatives (Spyros Panagiotopoulos, personal communication, April 21, 2021). (Figures 4.2-4.7)

In the following years, interest in the collection was low. A novice monk, Spyros Panagiotopoulos, printed the images from some of the plates on photographic paper (Spyros Panagiotopoulos, personal communication, April 21, 2021). Subsequently the boxes were moved from one storage room to another and finally forgotten again. Moving of the plates before and after their discovery in the 1990s proved to be damaging. Many suffered cracks, others broke into pieces, and chemical interaction with biomaterials from rodents damaged the emulsion. (Figure 4.8)

During the renovation project of Saint Catherine's Library during 2005-2017, all manuscripts, printed books, and various objects of the Library were relocated and stored safely away from the construction works. For this purpose, two large rooms were prepared in the 1942 concrete building that includes the Library; both were located in the south-east wing on the ground and first floors (Father Justin Sinaites, 2018; Samy, 2017).

I was working in Saint Catherine's Monastery as camera operator for the Sinai Palimpsests Project, when the Librarian, Father Justin, invited me in October 2014 to inspect with him the collections in the upper storage room, mainly printed books and older photographic equipment. In the far corner, we found a pile of six carton boxes. Within them, we rediscovered photographic glass plates. By holding some of them against the ceiling light, we could identify their contents. For example, one was the negative image of a Byzantine Icon from Saint Catherine's collection of Icons (Figure 4.9). The Librarian granted me permission to investigate the plates, provided initial documentation and worked with me to find a better storage solution. This was the beginning of the of the Sinai Glass Plates Project.

4.2 Cataloging and Packaging

The project had no external funding and was done during my free time with equipment and conservation materials found onsite. For the first phase of the project in October 2014, I moved the carton boxes to a work room on the second level of the south-west wing of the concrete Library building, which had previously been used by conservation projects of the Monastery. The work room was equipped with large working surfaces, desks and basic conservation materials. The initial inspection and cataloging started on October 13, 2014.

The glass plates, stored in fragile large carton boxes as in figure 4.8, had been placed horizontally one on top of the other, thus adding weight to the bottom stack of the glass layers. Dust and dirt were very much evident, as well as small portions of unwanted rodent-origin biomatter. Inside the larger boxes, the plates appeared to be stored inside their original packages, of which I counted 90. On detailed inspection, it appeared that most glass plates had been put in boxes in random groups of approximately 10 to 20 plates. (Figure 4.10)

Table 4.1

Number of boxes, for each dimension and number of make as indicated by the box label

Carton boxes	
10x15 cm	6
18x24 cm	84
Total Boxes	90
Make	
Gevaert	33
Kodak	28
ILFORD	7
ORWO	1
FORTE	1
Ferrania	1
"no information"	19

The labels of the original boxes provided the details of the make and the technical components of the emulsion used to capture images.

Table 4.2

Glass plate characteristics as indicated by descriptions on labels of boxes

Make	Technical information
Gevaert	Chromosa,Tropical, 500H&D, 30109, ES
Gevaert	Sensima, Orthochrom, 18×24, 18923
Kodak	Polychrome, tropical, ultra-rapid, 18×24 cm
ILFORD	Zenith, (H.&D. 400) Extra sensitive
Gevaert	Sensima, Super, 18×24, 24248
Gevaert	Chromosa,Tropical, 500H&D, 30109, ES
Gevaert	Chromosa, Super, high speed, Tropical, 1200 H&D, 31952, AB
Kodak	Polychrome, tropical, ultra-rapid, 10×15 cm
FORTE	Normal, BN4, Bromofort, 100, 18×24, Tropical, 3 5 290
ferrania	Lastre, cappelli, superorto anti-alo, 1/2 Dozz. 18-24, N.5785
Perutz	Silbereosin, Orthochromatisch, 4-D-0-10, 22137, 72 Duzu, 18×24

Each of the original carton boxes had a handwritten number, either written directly on the box or on a piece of paper placed inside the box. This numbering permitted both rearrangement of the boxes in numerical sequence as well as allowing identification of missing ones. The immediate need was proper storage in individual envelopes using materials available at the Monastery. From acid-free conservation paper, I created envelopes for individual plates that were not completely air-tight, thus allowing the object to “breathe” and not entrap dangerous gases (Wagner & Martin, 2016). In a repetitive one-person work process, each plate was measured and wrapped in paper cut to size. This permitted placing a serial number as a unique identifier on each object. (Figures 4.11)

My next step was to develop a spreadsheet database that would include all information necessary to make each glass plate searchable and easily identifiable with metadata and a digital photographic copy.

The workflow was designed as follows:

1. Unbox glass plates.
2. Lightly clean using a conservation brush.
3. Place on conservation paper.
4. Note identifier number on outer side of conservation paper.
5. Note characteristics in excel database on the same identifier number.
6. Fold conservation paper to create folder with the identifier number visible on the outside.
7. Place envelope *vertically* inside a larger durable plastic box lined with protective foam pillows on all sides, bottom, and top.
8. Number box with notes of contents.

According to my work-journal, the date of achievement of each milestone was:

Table 4.3

Milestones achieved in cataloging from 2014 to 2015

Date	Activity	Box
14/05/2014	Investigating-Cataloging	1
15/10/2014	Cataloging	2-3
16/10/2014	Cataloging	4-5
17/10/2014	Cataloging	6-8
18/10/2014	Cataloging	9-14
20/10/2014	Cataloging	15-16 (broken plates)
21/10/2014	Cataloging	17, 19, 20, (18 NOT found)
22/10/2014	Cataloging	21, 22
15/05/2015	Cataloging	23, 24
16/05/2015	Cataloging	25, 18 (added), 26, 27
18/05/2015	Cataloging	28, 29, 30, 31
19/05/2015	Cataloging	32, 33, 34
20/05/2015	Cataloging	35, 36, 37, 38
21/05/2015	Cataloging	39, 40, 41, 42
22/05/2015	Cataloging	43, 44, 45, 46
23/05/2015	Cataloging	47, 48
01/10/2015	Cataloging	49, 50, 51, 52

02/10/2015	Cataloging	53, 54, 55, 56
03/10/2015	Cataloging	57, 58, 59, 60, 61
05/10/2015	Cataloging	62, 63, 64, 65, 66
06/10/2015	Cataloging	67, 68, 69, 70, 71
07/10/2015	Cataloging	72, 73, 74, 75
08/10/2015	Cataloging	76, 77, 78, 79, 80
09/10/2015	Cataloging	81, 82, 83, 84, 85
10/10/2015	Cataloging	86, 87

4.3 Digital Database

After this initial sorting, wrapping and entry into the spreadsheet database, it was clear that a proper cataloging including documentation of the physical state of the objects was necessary for research and analysis. With the help of Vasiliki Kokla, an expert on conservation of glass plates, I developed the matrix for the characteristics to be noted and the method to evaluate physical condition of the object, particularly the chemical emulsion, which is the most important and fragile component. Here again, the dry Sinai climate helped the passive conservation. The condition of the objects was noted, based upon the appearance and damaged spots of the emulsion, but the evaluation also includes the condition of the glass plate: whole or fragmented into a recorded number of pieces. Thus, the spreadsheet database contains the following fields and entries:

Table 4.4

Information noted for each individual glass plate, descriptions, and samples

Fields	Range of possible values	Example
Serial number	Unique identifier correlating physical object with digital copy and metadata G0000-G9999	G0959
Supporting material	Glass or single emulsion without glass	Glass

Dimensions	Physical dimensions of emulsion and glass plate: 18×24 or 10×15	18×24
Box number	Number of original carton box	77
Orientation	Vertical Horizontal orientation of the contents of the photograph	Vertical
Category	Category of the contents of the photograph: unknown people nature animals buildings icons manuscripts documents papyrus objects (one or any combination of the above)	People
Condition	Condition of emulsion on a scale of 0-5 1: Very poor 2: poor 3: almost good 4: good 5: very good	4
Pieces	Description of whole of fragmentary glass surface: 1 or -n- number	2
Year	Year or range of captured photograph when distinguishable	-
Photo notes	Notes observed from the context of the photograph: names of people or places, etc.	-
General notes	Notes observed on the physical object: condition or other characteristics	Broken corner
Imaged	Yes/No	Yes

This analysis also indicated which glass plates need immediate conservation. The majority are still in good condition, with 81.73% of the objects meeting grade 5 criteria (“very good” condition), special attention is needed though for the combined categories 1, 2, 3 which amounts to 6.36% (very poor, poor, almost good condition). (Figure 4.12)

4.4 Digitization and Permanent Storage

After conservation and cataloguing, the next step was digitization of the glass plates and their original boxes. The equipment used, given that no external funds were available, was from the personal equipment of Librarian Father Justin and the author. The capturing system consisted of a small folding table and a *Manfrotto* photographic tripod for the digital single reflex camera *Nikon D5300* (24.2 megapixels) in combination with a *Zeiss Makro Planar T* 2/50mm ZF.2* lens. Illumination came from a portable A4 size lightbox, which was ideal for providing light from below the surface of the glass plate negative. The light box was placed on top of the folding table and parallel to the camera above it.

The capturing system was operated from a laptop computer through a USB cable. All camera capture settings were set by the “CaptureOne 8” software, which set the light sensitivity to ISO 100 with a lens aperture of f/8 (after an initial experimentation this combination provided the ideal results in terms of sharpness and captured light). A small automated script was used for the naming convention of newly captured objects. After an image was captured, it was transferred directly to the computer and previewed on the monitor. The software automatically inverted the gray scale from the negative and cropped the picture to a predefined size. Files were saved in TIFF archival format to meet digital preservation standards and for best reproduction quality (dynamic range, optical resolution). Following digitization, all glass plates were stored in their newly constructed custom packaging. And each envelope placed vertically inside a larger durable plastic box lined with protective foam pillows on all sides, bottom, and top (the plastic durable boxes with small wheels for easy movement measure: 34 cm high, 74 cm long, 39 cm wide). (Figures 4.13)

The digitization was completed in eight days between two imaging sessions of the Sinai Palimpsests Project, from October 12th until December 11th 2015. It resulted in 1264 photographs as recorded below:

Table 4.5

Number of glass plates digitized from October 12, 2015 to December 11, 2015

Date	Captured images
------	-----------------

12/10/2015	276
13/10/2015	135
18/10/2015	73
19/10/2015	377
04/12/2015	56
05/12/2015	212
09/12/2015	73
11/12/2015	62
Total	1264

Digital files are currently preserved in local backups at the Sinai Monastery, accessible by the librarian.

4.5 Conclusions

This small-scale project of digitizing the 1264 glass plate negatives and saving them as archival positive images helps us see – and understand – aspects of life in the Monastery in the early 20th century. Activities that are long forgotten and faces that have now faded into the mist of time have reappeared. As a material, the glass plates and the light-sensitive emulsion preserved snapshots from a century ago in surprising quality. But this information may be forgotten and lost in the context of advancing technology and deterioration of the physical aspect of the image objects. The goal of my project was to make the transition of image format to preserve and make accessible the information. This transition adds the documentation in the form of metadata both about the content but also the history of how the images came to be.

We may attempt to understand the interests of the photographers based on the objects or situations that they chose to capture. I have tried to identify the context of each photograph and verify the origin of the photographer(s). This latter, however, remains an open question. Was the photographer a Sinai Monk named Damianos Papakostantinou, who by reports of monks alive today was at the time using such a photographic device? (His Eminence the Archbishop of Sinai and Sinai Monk Aaron Stellakis, personal communication, May 9, 2021). Or is the collection a sum of different photographers and periods? This question should be studied further but may never be

known for certain. When did the camera arrive to the Sinai Monastery? In a photograph from Arthur Hjelt in 1928 (Chapter 1.3.6) we see the photographic camera next to Archbishop Porphyrios III and a manuscript that appears to be Sinai Syriac 30 (Figure 4.14). Through the digitized photographs, we see and remember both faces and activities of the past. The recorded statistics indicate that the photographer(s) were most interested in documenting manuscripts (69.39%). But the images included only sample pages from handwritten documents rather than full codices. It is as if the author(s) wanted to sample and preserve only some parts of the manuscript collection. The next largest number of photos involves people (15.51%) and buildings (6.16%), often on the same images. (Figure 4.15)

To improve this understanding of the past in the future, the state of the collection needs to be monitored, the images need to be published, and research on the identification of photographers is required. Monitoring of plate condition is important to prevent further deterioration. Publication will permit a broader audience to understand life in the Monastery and, ideally, viewers contribute identifications of individuals and work processes. While “publication” in the core meaning of the term, is “outward-oriented,” it may also achieve an inward-pull in the Monastery to obtain additional information for a better understanding of the origin of those photos.

4.6 Figures of Chapter 4

Figure 4.1

Monks and Bedouins preparing Easter Eggs inside Saint Catherine's Monastery



Note. Glass plate G0879 from collection of glass plates at Saint Catherine's Monastery. Ten monks and two Bedouins, preparing Easter eggs, outside the north wall of Saint Catherine's cathedral

Figure 4.2

Photographic case of glass plates camera found in 1990 in the Panagia Chapel



Figure 4.3

Photographic accessories of glass plates camera



Figure 4.4

Photographic lens of glass plates camera

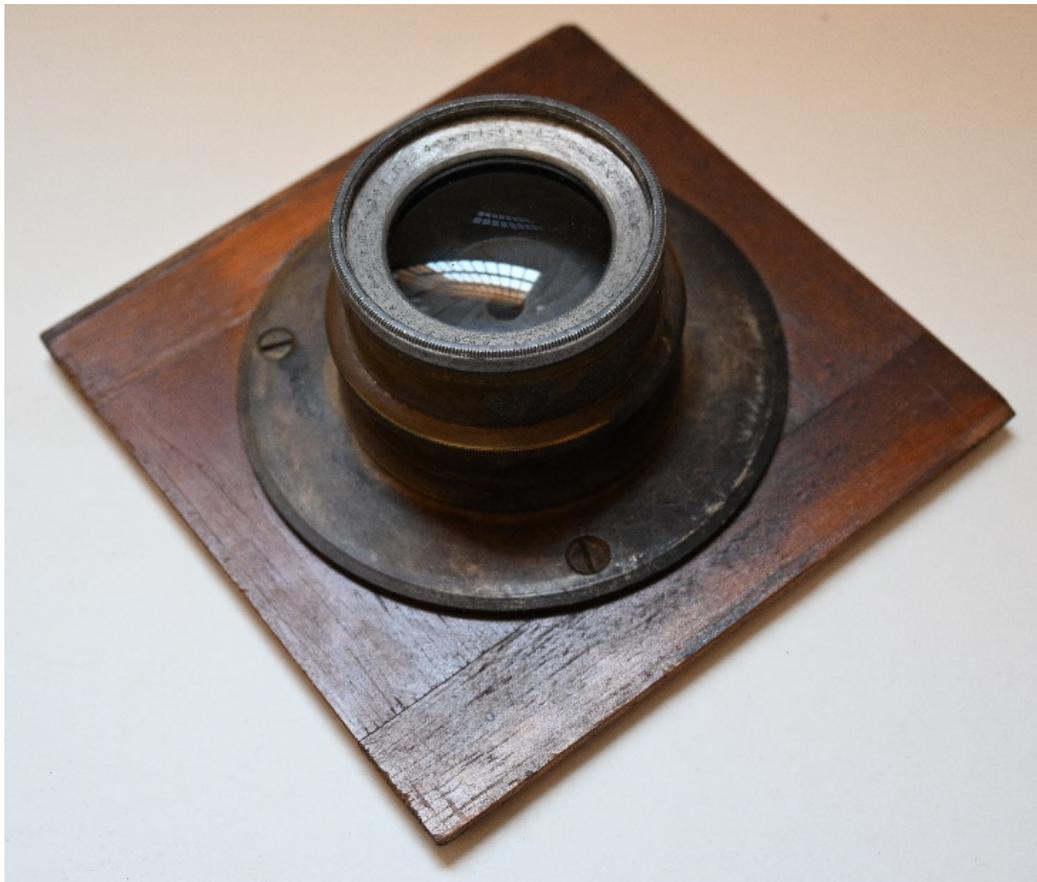


Figure 4.5

Emulsion holders for camera



Figure 4.6

Photographic camera contracted



Figure 4.7

Photographic camera assembled with lens and fully extended



Figure 4.8

Carton boxes as they were originally found in 2014



Figure 4.9

Glass plate negative on light box and developed digital file (cropped and color inverted)



Note. Glass plate G1003 from collection of glass plates at Saint Catherine's Monastery.
Christian Icon

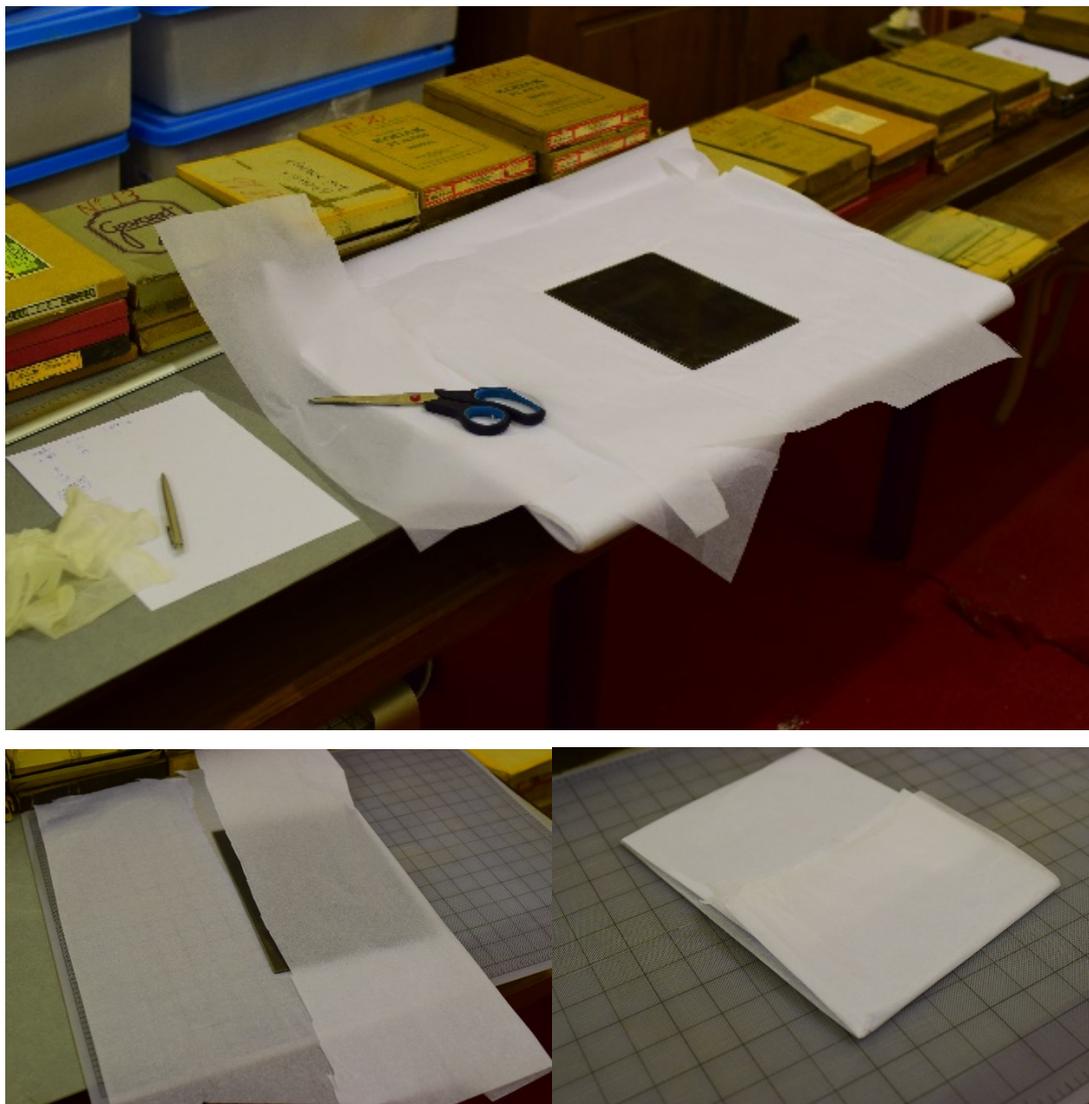
Figure 4.10

Glass plate packages of different make



Figure 4.11

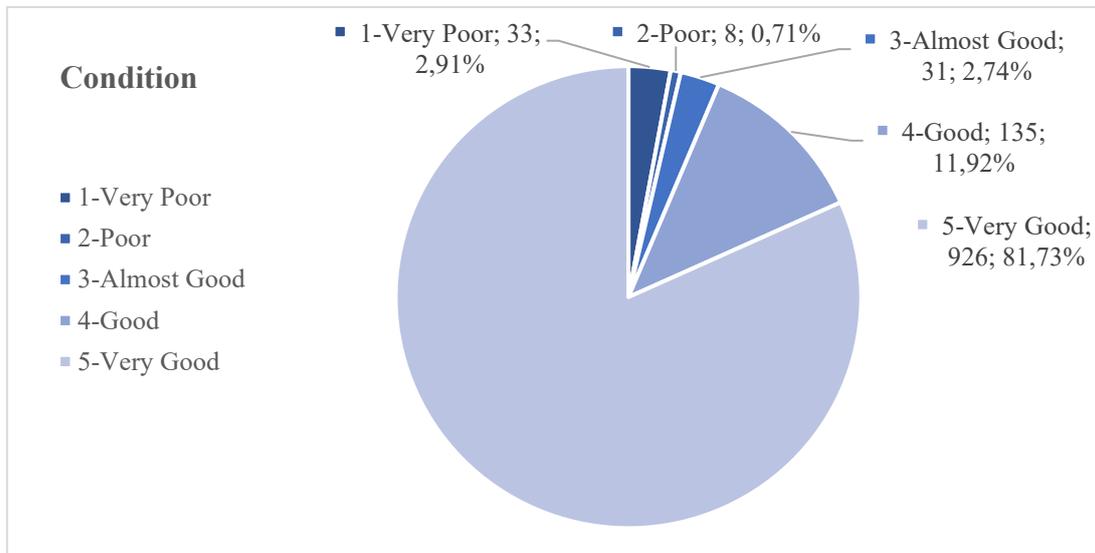
Procedure of creating an acid free paper envelope for each glass plate



Note. (top) Single glass plate on top of acid free paper cut to size, (bottom left) first of four folds during the creation of individual storage envelope, (bottom right) storage envelop with glass plate inside in final form

Figure 4.12

Condition of glass plates statistics



Note. Grade from 1-5 (very poor to very good)

Figure 4.13

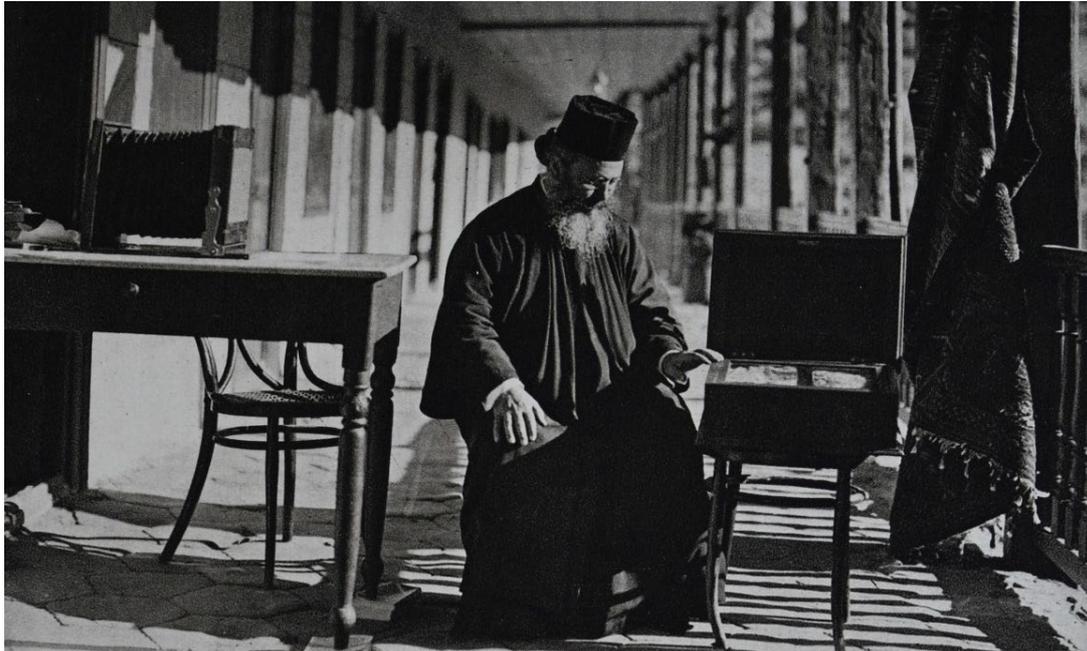
New packaging of glass plates in durable plastic boxes



Note. (top) glass plates stored vertically along with their original packaging, (bottom left) top protective foam along with number and contents of box, (bottom right) storage box ready

Figure 4.14

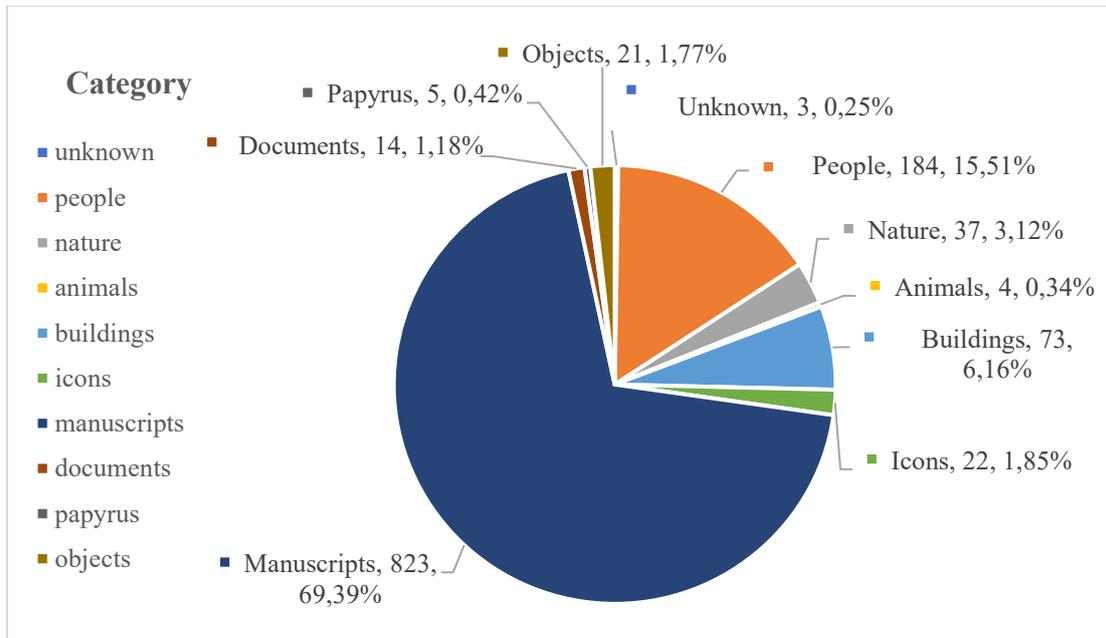
Archbishop of Sinai, Porphyrios III next to Sinai Syriac 30



Note. Photograph from Helsingistä Siinaille p. 122. (left) photographic camera, (center) Archbishop Porphyrios III, (right) Sinai Syriac 30

Figure 4.15

Category statistics of glass plates from the collection in total



Conclusions

In the very early stages of developing the idea for this dissertation, I was not aware of the extent of information that would be unraveled during the subsequent research. At the start of my voyage, I was planning to document a subject that held a special interest for me: the photography of manuscripts in the Sinai Library. Instead, what I found was a better understanding of the Sinai Monastery, which I hope has allowed me to contribute to the documentation of its history. After seven-hour drives from Cairo, I found myself in the center of the South Sinai Peninsula, surrounded by mountains of 2000 meters in height, with 6th-century walls built from the granite of those very mountains. Within these walls are ancient manuscripts, state-of-the-art photographic equipment, and glass photographic plates that captured moments from the lives of people of the 20th century. As strange and exciting as the experience may appear to be, it comes with numerous challenges. The obvious examples are the remoteness and the dry climate of the area, but more exquisite cases relate to fragile manuscripts that survived in conditions not found in other collections.

The combination of initial interest, challenges, and absence of consistent documentation guided my research. It also provided me with a better understanding of the manuscripts collection, the community of people who were interested in them, and the history of their preservation through photography. This concluding part of the dissertation will synopsise the research results on the history of past and modern photography projects and expeditions.

The importance of Sinai is well known in the religious world of Western and Eastern Christianity, as it was a pilgrimage destination even before the 6th century. The blooming life of monasticism led to the construction of the Byzantine fort and with it the first Library. Through the centuries manuscripts are gifted, transported by pilgrims, or copied on site adding to the growth of the collection. For the scholarly world of the West, it is not until the end of the Napoleonic wars that easier and safer travel is made possible, the Sinai Monastery becomes an attractive destination for explorers and scholars especially after the beginning of the 19th century. Explorers have reached the Monastery in the past, but now a systematic wave of scholars is coming in, aiming to see specifically the manuscripts and other art treasures. In the beginning of the 19th

century technology leaps forward, making portable devices that can capture photographs available to explorers.

It is not until 1889 that James Rendel Harris travels to Saint Catherine's with a photographic camera to capture images of the Sinai manuscripts. Previous researchers had either transcribed the manuscripts on site or returned to their home cities with the manuscripts for more leisurely study. Scottish twin sisters Agnes Smith Lewis and Margaret Dunlop Gibson, inspired by Harris, make the first step in the modern concept of manuscript preservation through photography. Lewis and Gibson journey to Sinai and dedicate most of their efforts to photographing the important manuscript Sinai Syriac 30 instead of removing it from the Library. In turn, their effort becomes an inspiration for many other expeditions to come. The most known and notable expedition is that of Wendell Phillips, who organized the mission now known as the "U.S. Library of Congress Microfilming Project" in 1950. With great aspirations for microfilming all manuscripts in the Library, the project actually photographed about half of them. Even so, this was deemed a success as it opened the doors to scholars on scholarly research of manuscripts from a remote Library. The microfilms were copied and distributed around the globe.

Shortly after, another expedition from the U.S. approached the Monastery in 1956. This time with broader questions, not only to the manuscripts, but also about the architecture and art of Byzantine icons. Kurt Weitzmann and George Forsyth were able to capture not only black and white photographs but also color ones, as technology had progressed once more, bringing to life through vivid colors miniatures and paintings of manuscript pages. The 1969 war affected the Monastery indirectly. Scholars from Israel arrived in the recently occupied Sinai (from the Six-Days war) with the interest of preserving the manuscripts by finishing the work that the Library of Congress in 1950 had not completed. The remarkably successful project was not widely known to the scholarly community and only recently gained more attention through the digitization of microfilms that were deteriorating in 2016, and the subsequent publication of the images on the internet.

1975 marks an important year in the history of the Monastery with the discovery of more than 1500 manuscripts, long forgotten in an enclosed room of the 6th-century north wall. Official announcements of the discovery are made in 1981, but it is not until 1998

that a catalogue is published, even if insufficient. The catalog includes descriptions of the “New Finds” and some photographs of manuscripts. Inspired by the discovery, several expeditions took place in the Sinai Library to facilitate specific language groups of the new collection. Georgian and Slavonic manuscripts attract a special interest, and at the same time important evidence of the long-lost Caucasian Albanian language emerges. With the advancement of digital photography, new equipment was introduced to support preservation and study of the collection. The Sinai Monastery attempted for two decades (1997-2017) to digitize the collection of manuscripts on its own. Librarian Father Justin realized the importance of a systematic approach for a large-scale project with multiple collaborators and photographers. In the meantime, attention was refocused upon the erased texts of the Sinai Library. In 2011, the Sinai Palimpsests Project (SPP) began efforts for multispectral imaging of 7400 pages of palimpsests. This was concluded in 2017. With my participation as chief photographer in this project, I found my interest placed upon the history of photography and established the foundation for my dissertation. In 2018, the systematic digitization of all the manuscripts of the Sinai Library began through the Sinai Library Digitization Project (SLDP), an effort to publish 4500 manuscripts online with the support of the Early Manuscripts Electronic Library, and the University of California Los Angeles. This project is still ongoing.

Having brought all of the photographic expeditions dedicated to the preservation and study of manuscripts in the Sinai Library together for the first time, I was able to see interesting patterns and make comparisons. From the 19 known photographic expeditions and projects that took place between the 19th and 21st centuries, only three of them were “Greek” initiatives. This shows the openness of the Greek Orthodox Monastery of Saint Catherine to “foreign” scholars to some degree to study and promote the heritage that monks have been keeping safely in the Sinai desert. Even when the Sinai Monastery felt that contractual agreements were not met by the Library of Congress (Chapter 1.3.7), it would still invite other groups to work with the manuscripts while retaining a memory of the event (Chapter 1.3.9, National Library of Israel). More openness meant more support for the Sinai Monastery.

Comparing these 19 known expeditions, the main common challenge is the remote location. Camera equipment and emulsions of early explorers and scholars were recorded for each expedition since it is the principal factor for durability and readability

of the results. From the 19th century, scholars had to import fragile glass plates on camels. In the 20th century, electricity was produced by diesel generators, but was so unstable that it resulted in differences in exposures of the photographs (darker or brighter). In the 21st century, electricity fluctuations still can damage sensitive electronic devices unless regulated. Support for repairing damaged equipment in the Sinai desert remains difficult, so project organizers still need to plan for the unexpected, just as they had to do 100 years ago.

The second part of my dissertation is dedicated to contemporary digitization efforts in the Sinai. I have been and am part of these in first person. Explaining what a palimpsest is and why it is important to study the erased layers of manuscripts, I listed previous approaches and lessons learned from past expeditions. The technology has now advanced to enable adoption of a non-invasive policy for the study of historical treasures. The main focus of photographic expeditions has shifted to the collaboration of a broad range of sciences. Computer technicians, optical experts, and imaging scientists work together with data managers, scholars, and photographers. The goal is to produce objective results that can be studied by a broad range of researchers and not just by a single individual, as was the case previously. This development would not have been possible without the pioneering work of researchers of the past, even though they damaged the manuscript objects (literary and figuratively), they were able to shed light on the Sinai palimpsests and attract attention to the collection.

The first attempt at palimpsest imaging used chemicals and exposure to the most intense of light sources (the sun), but the light sources in the Sinai Palimpsests Project were light-emitting diodes (LEDs) that generate light by electronic transitions and not as a byproduct of incandescent heating. Significant focus was directed at computer processing algorithms and at identification of the texts, as well as collection of metadata for support of online publication. The result of this project was the discovery of 307 different undertext documents that add significant to the scholarly corpus. The project also contributed to the technological advancement of spectral imaging. The Sinai Palimpsests Project built upon the successful techniques of previous projects, such as the Archimedes Palimpsest project, but also introduced innovations, such as transmissive light sources and advanced image processing techniques. These new methods now are commonly used by other spectral imaging project around the world. My personal discovery, from inside the dark imaging room, was the text and image of

a 6th-century medical recipe that prescribes to mix and apply the plant “Phileterion” in case of a scorpion bite.

The successful record of the Sinai Palimpsests Project encouraged the Monastery to invite its collaborators (EMEL and UCLA) to carry on the digitization of the complete Sinai manuscripts collection. As director of imaging, I encountered similar challenges to those of past explorers and scholars. Heavy and fragile photographic equipment had to be transported and installed in the Sinai desert. Space is a particular issue inside a 6th century fort, and new infrastructure for the electrical and computer networks had to be installed in a room beneath the renovated Library in the south-east wing of the Monastery. The result is a state-of-the-art photographic laboratory with four digitization stations and dedicated storage servers for the Sinai manuscripts collection. Having prioritized care for the fragile important objects, I designed an efficient and safe workflow for the digitization procedure.

Special issues regarding file naming of digital images and recording of information were resolved with the experience accumulated from the Sinai Palimpsests Project and the exchange of information between other digitization institutions as the Biblioteca Apostolica Vaticana and the Cambridge University Library. The result of this work is the online publication of 400.000 images online (as of July 2021), including manuscripts from both the Old and the New Finds collection, with plans to increase the count steadily to 1.500.000 pages upon completion of the digitization of the Sinai Library. This is the first time that the New Finds collection is systematically presented to the broad public and made available to all researchers open access/free of charge.

The closing chapter of the dissertation deals with a forgotten collection of photographic glass plates exposed early in the 20th century. During my visits to the Sinai, I developed a special interest in these plates which were located in six neglected cardboard boxes. With the support of the Librarian Father Justin Sinaites, I cataloged, digitized, and created a solution for long term storage.

The resulting digital database of glass plates includes 1264 individual objects. Each is described by its physical properties (dimensions and conservation assessment), as well as contents of the photographs grouped by genre. The glass plates contribute to a better understanding of the history of Saint Catherine’s Monastery in the early 20th century, as they depict buildings, objects, people and activities of the past. From my work with

the photographic collection, further questions remain to be answered. Who were the photographers? When were the photographs captured? What was the reason for the documentation of specific objects? These questions seem a promising topic for further research but may never be known for certain.

In conclusion, the research of the photographic history of Saint Catherine's Library encourages the following points to emerge.

1. The remoteness and isolation of the Sinai Monastery has provided the location for safekeeping of objects for centuries, but the isolation is still a challenge for modern researchers who wish to study objects in the Library.
2. With the advancement of technology, and especially in the photography field, it was quickly realized the importance of photographic reproductions as method of preservation for cultural heritage treasures, as are the manuscripts of Saint Catherine's Monastery.
3. The Sinai Monastery may have not always been easily accessible but has made significant efforts to promote its treasures through the study and invitation of scholars and photography projects.
4. The application of spectral imaging makes formerly lost texts readable and made a forgotten written history accessible again. This aspect of discovery reflects not only on the material analysis of manuscripts as archaeological objects, but also contributes to the study of the community of people who used, transported, and created these documents. The archaeological buildings and objects of the Monastery constitute an environment that is both self-contained and widely connected to a human-spiritual ecosystem.
5. That being said, something is lost in the process of photography and digitization of the manuscripts. The physical aspect of the objects, the feeling of touch, cannot be replicated by electronic systems, at least not yet. To partially overcome this challenge, consistent information in the form of metadata must be recorded.

Bibliography

- Adams, F. (1844). *The Seven Books of Paulus Aegineta*. Sydenham Society.
- Aetheria. (1948). *Journal de voyage*. (H. Pétré, Ed.) Éditions du Cerf (Original work published ca. 380 C.E.)
- Agnes Smith Lewis. (1898). *In the Shadow of Sinai: A Story of Travel and Research from 1895 to 1897*. Macmillan & Bowes.
- Aleksidze, Z., & Blair, B. (2003). Caucasian Albanian Alphabet Ancient Script Discovered in the Ashes. *Azerbaijan International*, 11.3.
https://www.azer.com/aiweb/categories/magazine/ai113_folder/113_articles/113_zaza_script_ashes.html
- Aleksidze, Z., Shanidze, M., Khevsuriani, L., Kavtaria, M., & Meskhi, T. (2005). *Catalogue of Georgian manuscripts discovered in 1975 at St. Catherine's Monastery on Mount Sinai*. Greek Ministry of Culture - Mount Sinai Foundation.
- Amantos, K. (1928). *Sinaitika mnīmeia anekdota*. Syllogos pros diadosin ofelimon vivlion.
- Amantos, K. (1953). *Syntomos Historia tes Ieras Mones tou Sina*. Etaireia Makedonikon Spoudon.
- Baxes, G. A. (1994). *Digital image processing: Principles and applications*. Wiley.
- Bayer, B. (1968). *Checklist of the Manuscripts in the Library of the Monastery of St. Catherine in Sinai*. The Jewish National and University Library.
- Benešević, V. N. (1912). *Monumenta sinaitica, archaeologica et palaeographica* (Vol. 1). Tipografija Imp. Akad. Nauk.
- Benešević, V. N. (1925). *Monumenta sinaitica, archaeologica et palaeographica* (Vol. 2). Pamiati Akademija Nikodima Pavlovicha Kondakova.
- Benešević, V. N. (1937). *Les manuscrits grecs du mont Sinai et le monde savant de l'Europe depuis le XVIIe siècle jusq' à 1927*. Verlag der "Byzantinisch-neugriechischen jahrbücher.

Bensly, R. L., Harris, J. R., Burkitt, F. C., & Lewis, A. S. (1894). *The Four Gospels in Syriac: Transcribed from the Sinaitic Palimpsest*. Cambridge University Press.

Bruton, D. (2021). *Wavelength to Colour Relationship*. *Academo.Org*.
<https://academo.org/demos/wavelength-to-colour-relationship/>

Caner, D., Price, R., Bladel, K. van, & Brock, S. P. (2010). *History and hagiography from the late antique Sinai: Including translations of Pseudo-Nilus' Narrations, Ammonius' Report on the slaughter of the monks of Sinai and Rhaitous, and Anastasius of Sinai's Tales of the Sinai fathers*. Liverpool University Press.

Clark, K. W. (1953). Exploring the Manuscripts of Sinai and Jerusalem. *The Biblical Archaeologist*, 16(2), 22–43.

Color management solutions | basicColor | Engineering office Dipl.-Ing. Karl Koch. (2021). <https://www.basiccolor.de/>

Curtis, V., & Alexander, A. (2004). *Matson (G. Eric and Edith) Photograph Collection, Available Online | Library of Congress*.
<https://www.loc.gov/collections/g-eric-and-edith-matson-photographs/>

Dart, J. (1985, December 21). *One of Oldest Manuscripts of New Testament: Photo Technique Renews Ancient Gospels Text*. Los Angeles Times.
<https://www.latimes.com/archives/la-xpm-1985-12-21-me-3003-story.html>

Dmitrievskii, A. (1856). *Russkaïa Dukhovnaïa Missiâ v Ierusalime*. Издательство Олега Абышко : Императорское Православное Палестинское общество : Паломнический центр Московского Патриархата.

Dumbarton Oaks. (2008). *Kurt Weitzmann Photographs of Manuscripts, 1980s-1990s, PH.BZ.008, Image Collections and Fieldwork Archives*. Trustees for Harvard University, Washington, D.C.

Easton, R. L., & Kelbe, D. (2014). *Statistical Processing of Spectral Imagery to Recover Writings from Erased or Damaged Manuscripts*. *Manuscript Cultures*(7).

Emery, D., & Rapp, C. (2018). KatIkon: A Digital Catalogue as Multi-Purpose Tool. In P. Degni, P. Eleuteri, & M. Maniaci (Eds.), *Greek Manuscript Cataloguing: Past, Present, and Future*. Brepols.

- Epp, E. J. (1986). Review of *Specimina Sinaitica: Die datierten griechischen Handschriften des Katharinen-Klosters auf dem Berge Sinai 9. bis 12. Jahrhundert*, by D. Harlfinger, D. R. Reinisch, G. Prato, & J. Sonderkamp. *Journal of Biblical Literature*, 105(2), 361–362.
- Falcetta, A. (2020). *The daily discoveries of a Bible scholar and manuscript hunter: A biography of James Rendel Harris (1852-1841)*. Bloomsbury Publishing Plc.
- Falk, D., Brill, D., & Stork, D. (1986). *Instructor's manual to accompany Seeing the light: Optics in nature, photography, color, vision, and holography*. Harper & Row.
- Father Justin Sinaites. (2014). The Sinai Palimpsest Project. *Sinaiticus*, 4–5.
- Father Justin Sinaites. (2018). Monastery Celebrates Library Renovation, Apse Mosaic Conservation. *Sinaiticus*, 4.
- Feller, R. (1994). Aspects of Chemical Research in Conservation: The Deterioration Process. *Journal of the American Institute for Conservation*, 33, 91–99.
- Gau, M., Miklas, H., Lettner, M., & Sablatnig, R. (2011). Image Acquisition & Processing Routines for Damaged Manuscripts. *Digital Medievalist*, 6.
- Gibson, M. D. (1894). *Catalogue of the Arabic MSS. in the Convent of S. Catharine on Mount Sinai*. C.J. Clay and Sons.
- Gibson, M. D., & Lewis, A. S. (1893). *How the codex was found: A narrative of two visits to Sinai from Mrs. Lewis's journals, 1892-1893*. Macmillan and Bowes.
- Gippert, J. (2007). The Application of Multispectral Imaging in the Study of Caucasian Palimpsests. *Bulletin of the Georgian National Academy of Sciences*, 175, 168–179.
- Gippert, J., Schulze, W., Aleksidze, Z., & Mahé, J.-P. (2008). *The Caucasian Albanian palimpsests of Mt. Sinai*. Brepols.
- Glykeis, N. (1817). *Perigrafí iera tou Agiou kai Theovadistou orous Sina*. Ieras Vasilikis Monis tou Agiou kai Theovadistou “Orous Sina.”
- Grants | *The Ahmanson Foundation*. (2021).
<https://theahmansonfoundation.org/grantsearch/keywords/Toward%20key%20components%20of%20the%20Sinai%20Library%20Digitization%20Project/>

Gray, R. (2017, August 9). *The Invisible Poems Hidden in One of the World's Oldest Libraries*. The Atlantic. <https://www.theatlantic.com/science/archive/2017/08/sinai-peninsula-hidden-texts/536313/>

Grusková, J. (2010). *Untersuchungen zu den griechischen Palimpsesten der Österreichischen Nationalbibliothek: Codices Historici, Codices Philosophici et Philologici, Codices Iuridici*. Verlag der Österreichischen Akademie der Wissenschaft.

Harlfinger, D., Reinsch, D. R., & Sonderkamp, J. (1983). *Specimina Sinaitica: Die datierten griechischen Handschriften des Katharinen-Klosters auf dem Berge Sinai 9. Bis 12. Jahrhundert*. D. Reimer.

Harris, J. R. (1890). *Biblical fragments from Mount Sinai*. C.J. Clay and Sons.

Hatch, W. H. P. (1932). *The Greek manuscripts of the New Testament at Mount Sinai: Facsimiles and descriptions*. Geuthner.

Hjelt, A. (1929). *Helsingistä Siinaille*. Otava.

Hjelt, A. (1930). *Syrus Sinaiticus*. Akademische Buchhandlung.

Hunger, H., Hörandner, W., Cupane, C., Kislinger, E., & Raasted, J. (Eds.). (1982a). *Akten: XVI. Internationaler Byzantinistenkongress, Wien, 4-9 Oktober 1981.: Vol. 32.1*. Verlag der Österreichischen Akademie der Wissenschaft.

Hunger, H., Hörandner, W., Cupane, C., Kislinger, E., & Raasted, J. (Eds.). (1982b). *Akten: XVI. Internationaler Byzantinistenkongress, Wien, 4-9 Oktober 1981.: Vol. 32.4*. Verlag der Österreichischen Akademie der Wissenschaft.

Image 4 of Slavonic [Slavic] Manuscripts 5. Psalter [Psaltir'] (Latin). (n.d.). [Image]. Library of Congress, Washington, D.C. 20540 USA. Retrieved July 20, 2021, from <https://www.loc.gov/resource/amedmonastery.00279387946-ms/?sp=4>

Image Science Associates. (2021). <http://www.imagescienceassociates.com/>

Kasotakis, D. (2017a). *The Sinai Palimpsests Project*. "اكتشاف مخطوط أثري لـ"هييوقراط" في دير سانت كاترين, Cairo. <https://sis.gov.eg/Story/144001?lang=ar>

Kasotakis, D. (2017b, December). *The Sinai Palimpsests Project: Recovering texts erased 1,000 years ago through the systematic application of non-destructive spectral*

imaging techniques. The Other Voice of the Desert: Palimpsest Manuscripts of the Sinai Monastery, New Recovery Technologies, Discovery of Unknown Texts, Research Prospects, Athens.

Kasotakis, D. (2018a, November). *Sinai Palimpsests. Erased texts re-surface after hundreds of years with the use of non-destructive, systematic, spectral techniques. A project's implementation, results, and contribution to the world of digital cultural heritage*. Visual Heritage 2018 | CHNT 23, Wien.

Kasotakis, D. (2021a, April 20). *Recovery of the Sinai Fragments of Apollonius of Tyre*. The Early Illustrated Apollonius of Tyre: Perspectives on the Palimpsest Fragment in Sinai, Arabic NF 8, Toronto.

https://booksilksroadsapollonius.artsci.utoronto.ca/?page_id=16

Kasotakis, D. (2021b, July 1). *Imaging in remote locations: Challenges and workflow*. 3rd R-CHIVE conference, Rochester. <https://r-chive.com/conference-2021/>

Kasotakis, D. (2018b). Illuminating Techniques from the Sinai Desert: Spectral Imaging Inside one of the Oldest Libraries in the World Brings back to Life Rewritten and Forgotten Texts. Review of the Imaging Techniques and the Global Advantages on the Field that were Gained from the Sinai Palimpsests Project. *Third International Conference on Natural Sciences and Technology in Manuscript Analysis, 15*, 87–90.

Kasotakis, D. (Forthcoming). The Sinai Palimpsests Project: A View from the Imaging Room. In C. Rapp, G. Rossetto, J. Grusková, & G. Kessel (Eds.), *New Light on Old Manuscripts: The Sinai Palimpsests and Other Advances in Palimpsest Studies*.

Knox, K. (2021). *Hoku*. <http://www.cis.rit.edu/~ktpci/Hoku.html>

Kokla, V. (2019). *Diatirisi & Tekmiriosi Politismikon Agathon. Vasikes ennoies*. Institouto ARETHAS.

Kokla, V., & Tselikas, A. (2015). *Conservation of photographic glass negatives (1910-1930)*. Conference on Conservation Cultural Heritage: Challenges and Reviews.

Koufopoulos, P., & Myriantheos-Koufopoulou, M. (2017). A History of the Library at the Monastery of Sinai. *Sinaiticus*, 21–23.

Lettner, M., Diem, M., Sablatnig, R., & Miklas, H. (2007). Digital Image Analysis for the Investigation of Ancient Manuscripts. *Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology*, 171–177.

Lewis, A. S. (1894). *Catalogue of the Syriac MSS. in the Convent of S. Catharine on Mount Sinai*. Clay.

Lewis, A. S. (1910). *The Old Syriac Gospels or Evangelion Da-Mepharreshê: Being the text of the Sinai or Syro-Antiochene Palimpsest, including the latest additions and emendations, with the variants of the Curetonian text, Corroborations from many other MSS and a List of Quotations from ancient authors*. Williams and Norgate.

Library of Congress. (2012). *Manuscripts in St. Catherine's Monastery, Mount Sinai | Digital Collections | Library of Congress* [Digital Collection]. Library of Congress, Washington, D.C. 20540 USA. <https://www.loc.gov/collections/manuscripts-in-st-catherines-monastery-mount-sinai/about-this-collection/>

Magrini, S. (2008). I palinsesti greci della Biblioteca Medicea Laurenziana: Una introduzione. In S. Lucà (Ed.), *Libri palinsesti greci: Conservazione, restauro digitale, studio. Atti del Convegno internazionale* (pp. 163–169). Comitato nazionale per le celebrazioni del millenario della Fondazione dell'Abbazia di S. Nilo a Grottaferrata.

Manafis, K. A. (1990). *Sinai: Treasures of the Monastery of Saint Catherine*. Ekdokite Athenon.

Marchant, J. (2017, December 11). *Archaeologists Are Only Just Beginning to Reveal the Secrets Hidden in These Ancient Manuscripts*. Smithsonian Magazine. <https://www.smithsonianmag.com/history/archaeologists-only-just-beginning-reveal-secrets-hidden-ancient-manuscripts-180967455/>

McClure, M. L., & Feltoe, C. L. (1918). *The pilgrimage of Etheria*. Society for Promoting Christian Knowledge.

- MegaVision Cultural Heritage—EurekaVision*. (2021). http://www.mega-vision.com/cultural_heritage.html
- Migne, J.-P. (1864). *Patrologiae cursus completus* (Vol. 88).
- Miklas, H. (2007). *Slovo-ASO Project: St. Catherine's Monastery on Mount Sinai*. <http://slovo-aso.cl.bas.bg/sinai.html>
- Miklas, H. (2008). Zum Gang der Erforschung der glagolitischen Neufunde im Katharinenkloster auf dem Sinai. In W. Moskovich & S. Nikolova (Eds.), *The Holy Land and the Manuscript Legacy of Slavs* (pp. 48–59). Hebrew University of Jerusalem.
- Miklas, H., Gau, M., Kleber, F., Diem, M., Lettner, M., Vill, M., Sablatnig, R., Schreiner, M., Melcher, M., & Hammerschmid, E.-G. (2008). St. Catherine's Monastery on Mount Sinai and the Balkan-Slavic Manuscript Tradition. In H. Miklas & A. Miltenova (Eds.), *Slovo: Towards a Digital Library of South Slavic Manuscripts. Proceedings of the International Conference* (pp. 13–36). Bulgarian Academy of Sciences.
- Moritz, B. (1916). *Der Sinaikult in heidnischer Zeit*. Akademie der Wissenschaften in Göttingen.
- Netz, R., Noel, W., & Tchernetska, N. (2011). *The Archimedes palimpsest*. Cambridge University Press.
- Nikas, A. (1981). *Theodoros tes Raithou: Life, Works and his work Proparasceue*. Iera Moni tou theovadistou orous Sina.
- Nikolopoulos, P., Peltikoglou, V., Archbishop Damianos, & Archimandrite Sofronios. (1998). *Ta Nea Evrimata tou Sina*. Iera Moni kai Arxiepiskopi Sina - Ypourgeio politismou - Idryma Orous Sina.
- Pantelakis, E. (1939). *I Iera Moni tou Sina*. Vivliopoleion Ioannou N. Sideri.
- Parpulov, G. (2011). Greek and Latin Manuscripts at Sinai and the Scholarly World. In *Saint Catherine's Monastery at Mount Sinai: Its Manuscripts and their Conservation (Papers Given in Memory of Professor Ihor Ševčenko, 27 November 2010)* (pp. 34–42). Saint Catherine Foundation.

- Phillips, W. (1948). Recent Discoveries in the Egyptian Faiyum and Sinai. *Science (New York, N.Y.)*, 107(2791), 666–670.
- Piazzoni, A., & Jatta, B. (2010). *Conoscere la Biblioteca Vaticana: [Mostra nel Braccio di Carlo Magno, 11 novembre 2010-31 gennaio 2011]*. Biblioteca Apostolica Vaticana.
- Pickwood, N. (2004). The condition survey of the manuscripts in the monastery of Saint Catherine on Mount Sinai. *The Paper Conservator*, 28, 33–61.
- Pickwood, N., & Velios, A. (2006). Conservation and Continuity: Preserving the Library of the Monastery of Saint Catherine on Mount Sinai. *Studies in Conservation*, 51, 293–297.
- Princeton University. (2017). *The Sinai Icon Collection*. <http://vrc.princeton.edu/sinai/>
- Rabino, H. L., & Runciman, S. (1938). *Le monastère de Sainte-Catherine du Mont Sinai*. D. Spada.
- Rapp, C., & Phelps, M. (2017). The Sinai Palimpsests Project. *Sinaiticus*, 18–20.
- Rapp, C., Rossetto, G., Grusková, J., & Kessel, G. (Forthcoming). *The Sinai Palimpsests and Other Advances in Palimpsest Studies*.
- Rodriguez, H. (2019). *HR-1 SuperChroma – El blog de Hugo Rodriguez*. El blog de Hugo Rodriguez. <https://www.hugorodriguez.com/blog/hr-1-superchroma-eng/>
- Rossetto, G. (2019). *Three Euchologia Written on Reused Parchment (Sin. gr. 960, Sin. gr. 962, Sin. gr. 966 and their Membra Disiecta): A Contribution to the History of the Library of Saint Catherine's Monastery in the Sinai (Diss.)*. University of Vienna.
- Rossetto, G. (Forthcoming). Classical Texts Among the Palimpsests of the Monastery of St. Catherine (Sinai): An Overview. In C. Rapp, G. Rossetto, J. Grusková, & G. Kessel (Eds.), *New Light on Old Manuscripts: The Sinai Palimpsests and Other Advances in Palimpsest Studies*.
- Samy, M. (2017, December 16). *Egypt reopens ancient library in Sinai after renovations*. The Associated Press. <https://apnews.com/article/middle-east-ap-top-news-religion-egypt-6513fe0251914a9294c45f9481654b30>

- Sarigiannis, M. (2010). Contribution to the history of the Sinai Metochion of St Matthew in Candia. *Ariadne*, 16, 137–168.
- Schmidt, C., & Moritz, B. (1926). Die Sinai-Expedition im Frühjahr 1914. *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 25–34.
- Ševčenko, I. (1964). New documents on Constantine Tischendorf and the Codex Sinaiticus. *Scriptorium*, 18(1), 55–80.
- Sinai archive, folder 327*. (1969). Saint Catherine's Monastery.
- Soskice, J. M. (2010). *Sisters of Sinai: How two lady adventurers found the hidden gospels*. Vintage Books.
- Tarnanidis, I. (1988). *The Slavonic manuscripts discovered in 1975 at St Catherine's monastery on Mount Sinai*. St Catherine's Monastery, Hellenic Association for Slavic Studies.
- The National Library of Israel*. (2021). <https://www.nli.org.il/en>
- Thomson, F. (2003). Konstantin (in religion Porphyry) Uspensky and the Hilandar Monastery collection of manuscripts. In G. Matejic & E. Charles (Eds.), *Monastic traditions. Selected proceedings of the Fourth International Hilandar Conference* (pp. 305–341). Slavica Publishers.
- Tsamis, D. (1989). *To martyrologion tou Sina*. Iera Moni tou theovadistou orous Sina.
- Tsernota-beis. (2021). In *Wikipedia*.
<https://el.wikipedia.org/w/index.php?title=%CE%A4%CF%83%CE%B5%CF%81%CE%BD%CE%BF%CF%84%CE%AC%CE%BC%CF%80%CE%B5%CE%B7%CF%82&oldid=8688199>
- UCLA. (2017). *Sinai Palimpsests Project | Research Site*.
<https://sinai.library.ucla.edu/>
- UNESCO World Heritage Centre. (2002). *Saint Catherine Area*. UNESCO World Heritage Centre. <https://whc.unesco.org/en/list/954/>
- Velkovska, E. (2013). Sinai Chest I and the Collections of Sinai Fragments of James Rendell Harris. *Bollettino Della Badia Greca Di Grottaferrata*, 10, 223–252.

- Volkoff, O. (1972). *Voyageurs russes en Égypte*. Institut français d'archéologie orientale du Caire.
- Wagner, S., & Martin, M. (2016, August 15). *How Do I House Glass Plate Negatives?* National Archives. <https://www.archives.gov/preservation/storage/glass-plate-negatives.html>
- Wasserstein, D. (2003). Why did Arabic Succeed where Greek Failed? Language Change in the Near East after Muhammad. *Scripta Classica Israelica*, 22, 257–272.
- Weitzmann, K., & Galavaris, G. (1990). *The Monastery of Saint Catherine at Mount Sinai: The illuminated Greek manuscripts*. Princeton University Press.
- Williams, A. (2017, March 1). *Ancient Parchments Reveal Old Texts Concealed by Newer Ones*. Magazine. <https://www.nationalgeographic.com/magazine/article/explore-ancient-manuscripts>
- X-Rite Color Management, Measurement, Solutions, and Software*. (2021). X-Rite. <https://www.xrite.com>