



PRELIMINARY INVESTIGATIONS FOR X-RAY IMAGING THE ARCHIMEDES PALIMPSEST USING ELEMENTAL X-RAY AREA MAPS AND STEREOVIEW ELEMENTAL X-RAY IMAGING

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Outline



- History
- Imaging & The Scientists
- The Archimedes Palimpsest
- Iron Gall Ink
- X-ray Fluorescence Imaging
- Elemental X-ray Area Maps (EXAM)
- Stereoview Elemental X-ray Images (SEXI)
- Summary & Conclusion
- Acknowledgements



History



Archimedes – *Born 287 B.C. & Died 212 B.C. (Sicily)*

Pens his works onto papyrus scrolls in Greek.

Papyrus Scrolls – *212 B.C. to 1,000 A.D.*

The original scrolls are lost or destroyed.

Handwritten copies made onto other scrolls.

Early Book – *1,000 A.D. (Constantinople)*

A handwritten copy of Archimedes treatises, including diagrams & calculations, is made in the original Greek and assembled into an early book.

Palimpsest – *1,200 A.D. (Constantinople)*

A Christian monk recycles the parchment in the Archimedes book turning the Archimedes book into a new prayer book.



History

Palimpsest – 1,200 A.D. to 1906 A.D. (Constantinople / Istanbul)

The prayer book is used for religious purposes and eventually stored at the Mar Saba monastery.

Discovered – 1906 A.D (Istanbul)

Danish philologist Johan Ludvig Heiberg discovers the palimpsest in the library of The Church of the Holy Sepulchre in Istanbul. He photographs many pages, transcribes much of the text and publishes his work.

Disappears – 1907 A.D. to 1930 (Istanbul)

The palimpsest is lost or stolen. Forged paintings of medieval portraits in gold leaf are applied to 4 pages.

Purchased – ~1930 A.D. (Istanbul) to 1991 A.D. (France)

A French family travels to Istanbul on a trip and purchases the palimpsest from a local dealer.



History



Appraised – 1991 A.D. (Paris, France)

The French family takes the palimpsest to Christie's in Paris for an appraisal. Christie's identifies the book as the Archimedes palimpsest worth \$0.8 to \$1.2 Million.

Sold – 1998

The Archimedes palimpsest sells at auction to an anonymous billionaire for \$2.2 Million.

Retrieving “Archie” – 1998 A.D. to Present

The owner loans the palimpsest to The Walters Art Museum in Baltimore, Maryland. A large international technical team has been assembled to work on “Archie”. The Walters Art Museum staff responsible for Archie includes Will Noel (curator) and Abigail Quandt (conservator).



Imaging & The Scientists

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Waters Institute



X-ray Fluorescence Imaging

Robert Morton, Children of the Middle Waters

Jason Gislason, Children of the Middle Waters

Gene Hall, Rutgers University

Uwe Bergmann, Stanford Linear Accelerator Center

Multispectral Imaging

Roger Easton, Rochester Institute of Technology

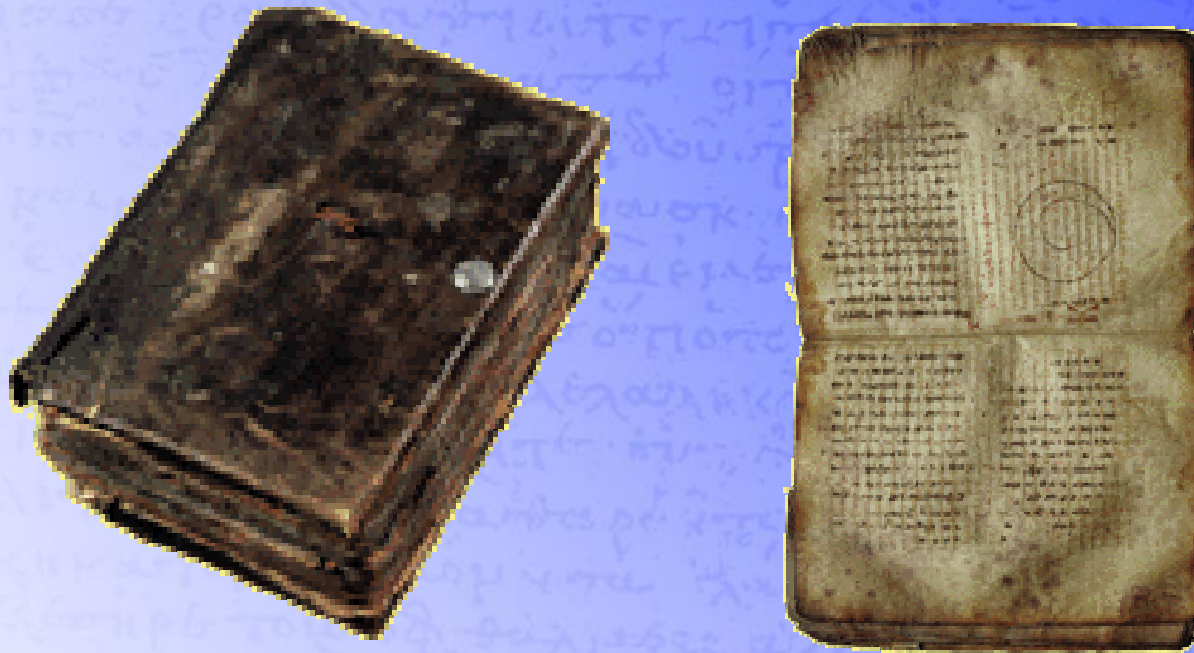
Keith Knox, Boeing LTS

William A. Christens-Barry, Johns Hopkins University



The Archimedes Palimpsest

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Christie's Images, Ltd., 1998



Iron Gall Ink



Iron gall ink is made from gallotannic acid, ferrous sulfate and a binder. Gallotannic acid is obtained by boiling plant or tree galls (reaction to insects / parasites). Ferrous sulfate is added to the water soluble gallotannic acid along with a binder such as gum Arabic. This makes a water soluble iron (II) gallotannate complex with good flow properties for writing.

Iron gall ink is a natural product containing iron and sulfur along with other trace elements. The ink has a weak color until applied to parchment, soaks in, and dries while exposed to air. The writing turns black as it ages (2 days) through oxidation to the iron (III) gallotannate.





X-ray Fluorescence Imaging

- Non-Destructive!!!!
- Element Specific Imaging with Great Sensitivity for Fe & S.
- Pulse Counting Technology – More Time = Better Image.
- Iron Imaging – Humid Air (Requirement)
- Sulfur Imaging – Best In Helium (Humidified?)
- Trace Element Imaging – P, Ca, Cu, Zn, etc.
- Both Positive and Negative Images
- Stereometric Perspective – Aid to Interpretation
- Digital with Highly Collimated Beam
- Results Treated Mathematically For Correlation Studies
(Both Element & Shape Recognition)



Elemental X-ray Area Maps

EDAX Eagle III

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Elemental X-ray Area Maps

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**Mounting Archie
Representative Page**

**Loading Archie
Forgery Painting**

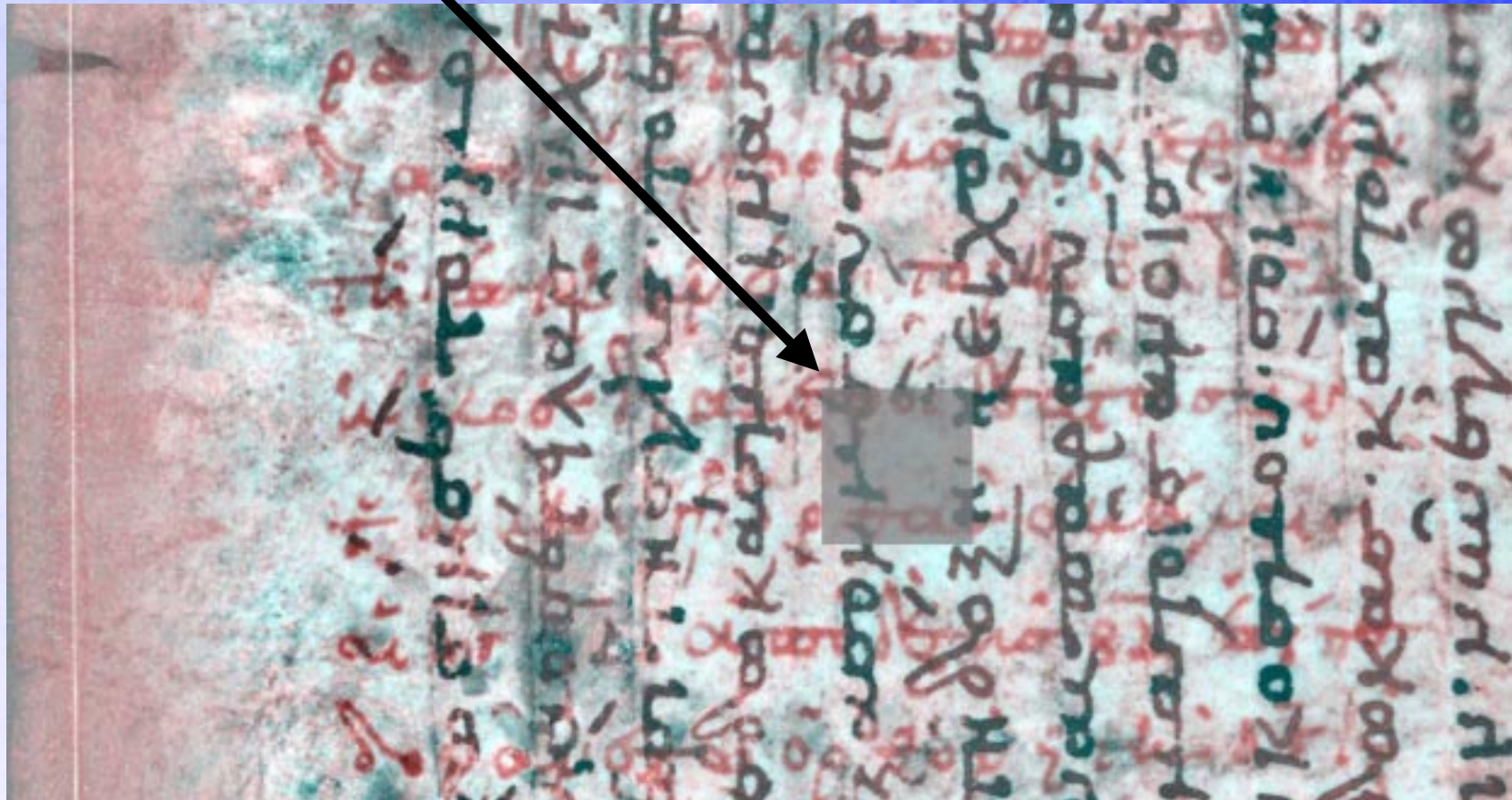


Elemental X-ray Area Maps

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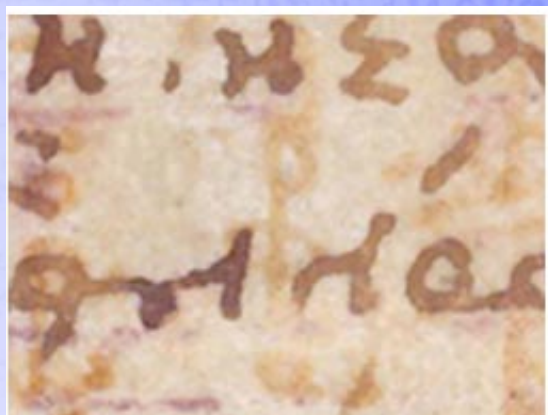


Region Of Interest

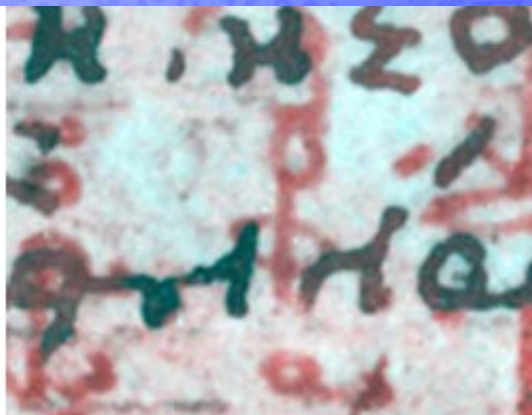


Elemental X-ray Area Maps

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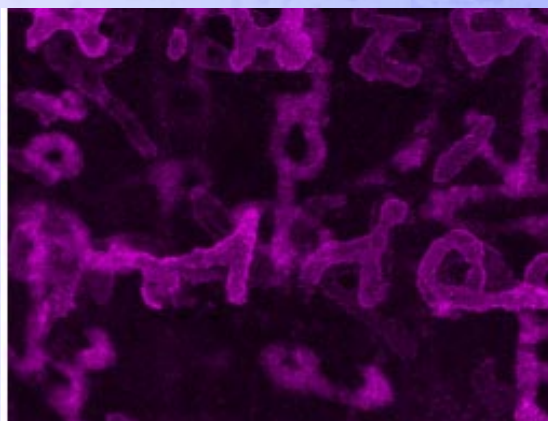
Photograph



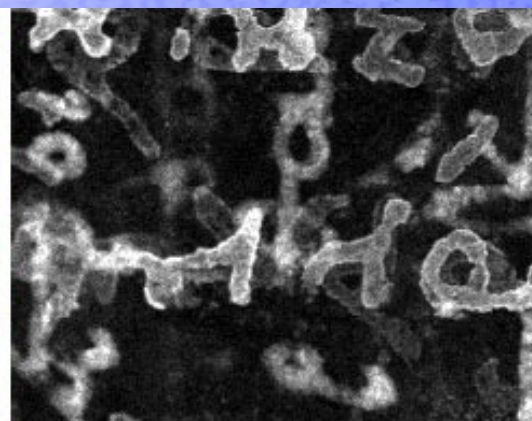
Multispectral

EDAX Eagle III

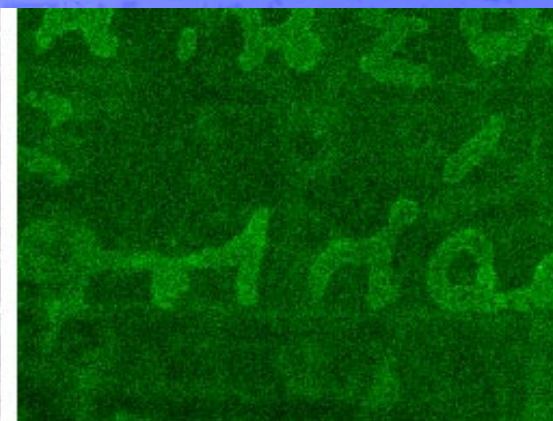
(Monodirectional Step Scan)



Fe K- α (Color)



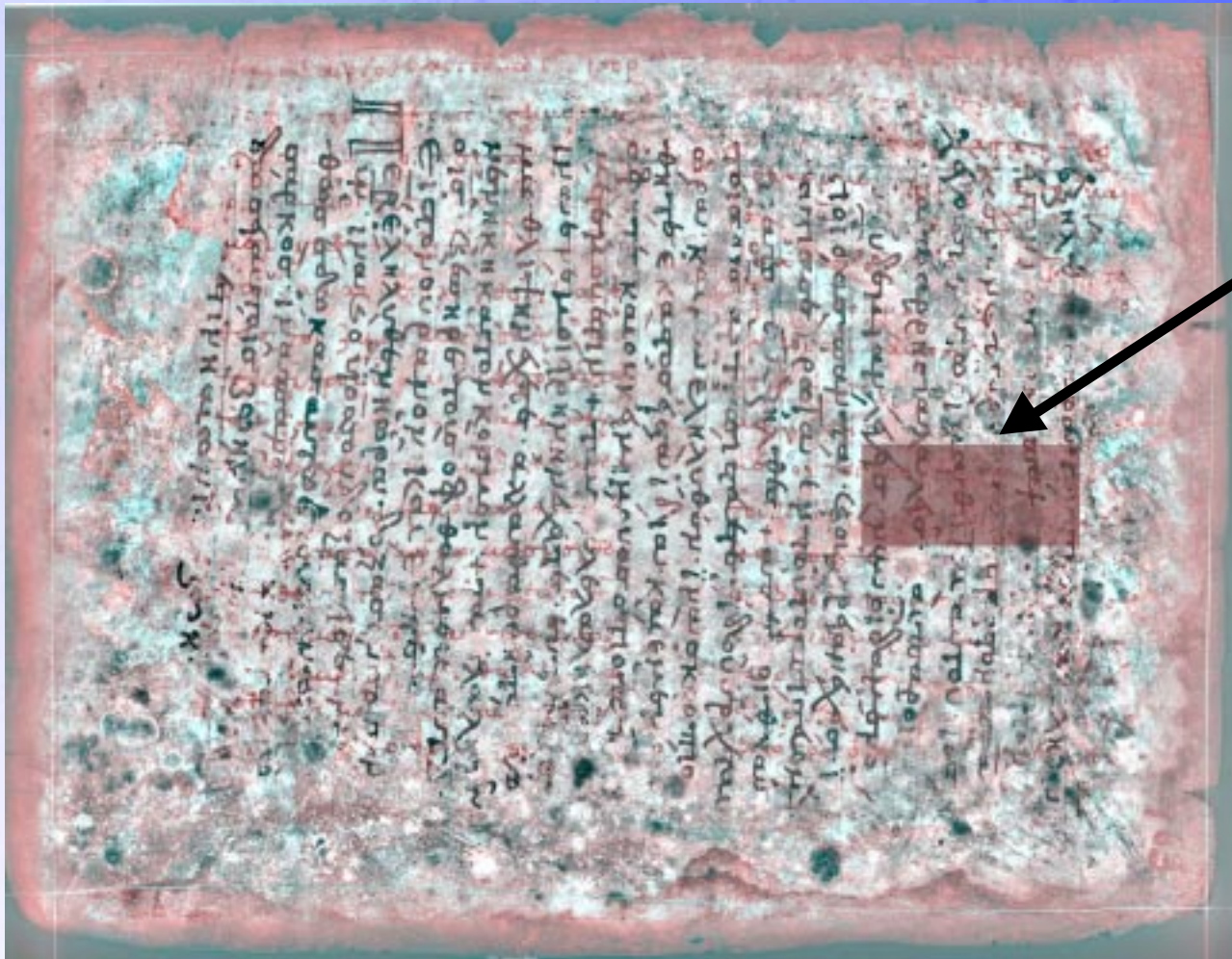
Fe K- α (Grayscale)



K K- α (Color)



Elemental X-ray Area Maps

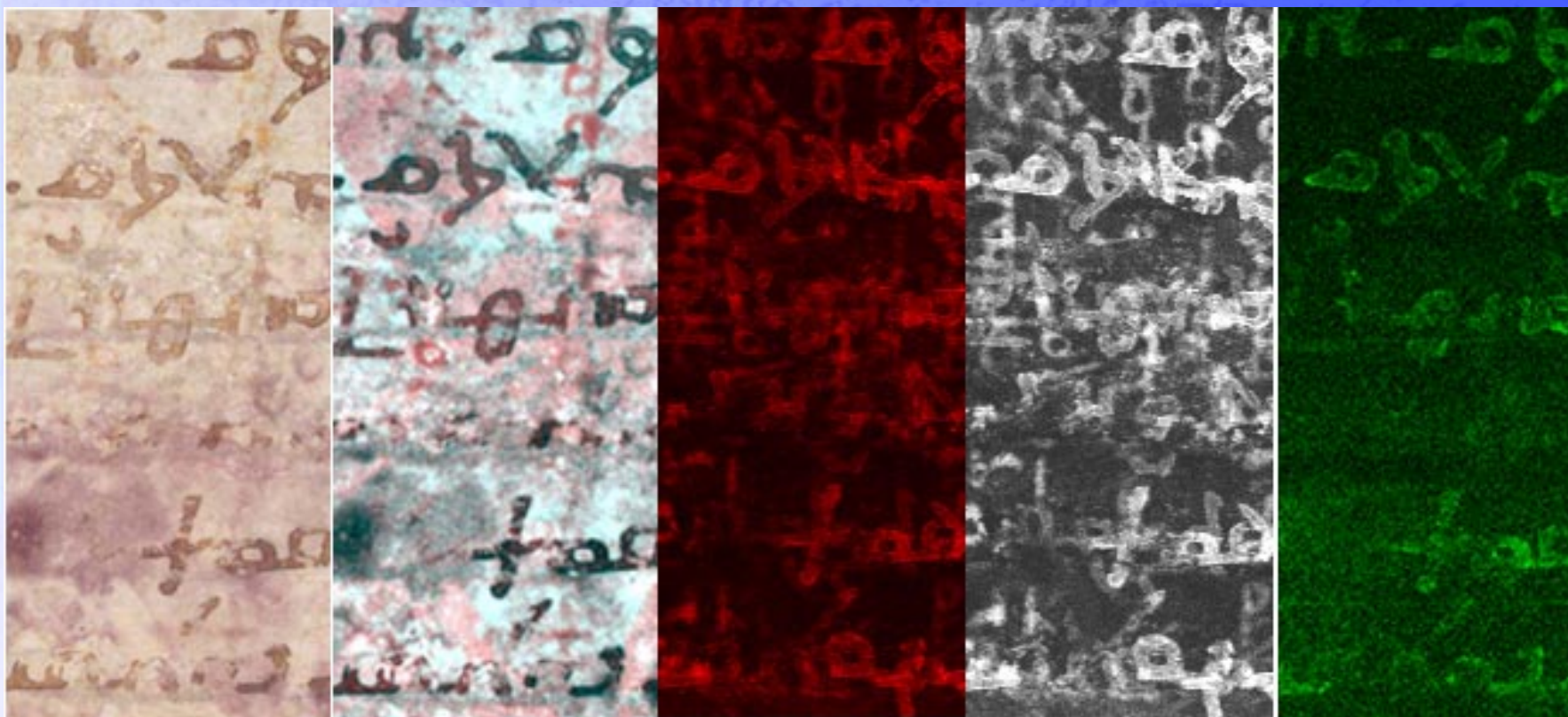


Region
Of Interest

Elemental X-ray Area Maps

EDAX Eagle III

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Photograph Multispectral

Fe K- α

Fe K- α

S K- α

Elemental X-ray Area Maps

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A Forgery Painting



EDAX Eagle III



Fe K- α

Photograph

Elemental X-ray Area Maps

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Region Of Interest



Elemental X-ray Area Maps

EDAX Eagle III

Photograph



Multispectral



Enhanced



Fe K- α



para eutheian

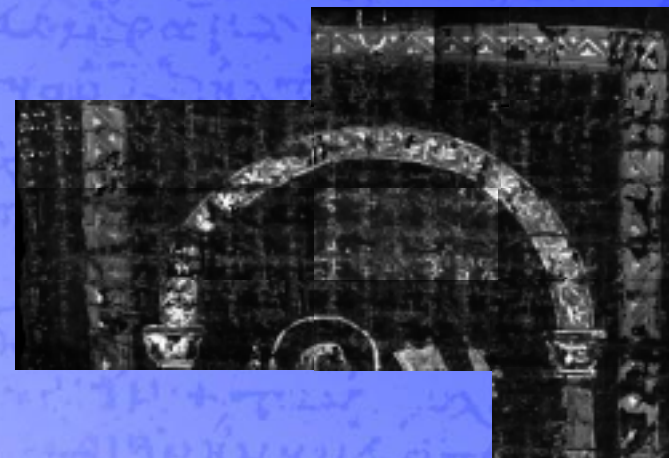
First Translated Word From Under A Forgery Painting! 4/2005



Elemental X-ray Area Maps

Stanford Linear Accelerator - SLAC

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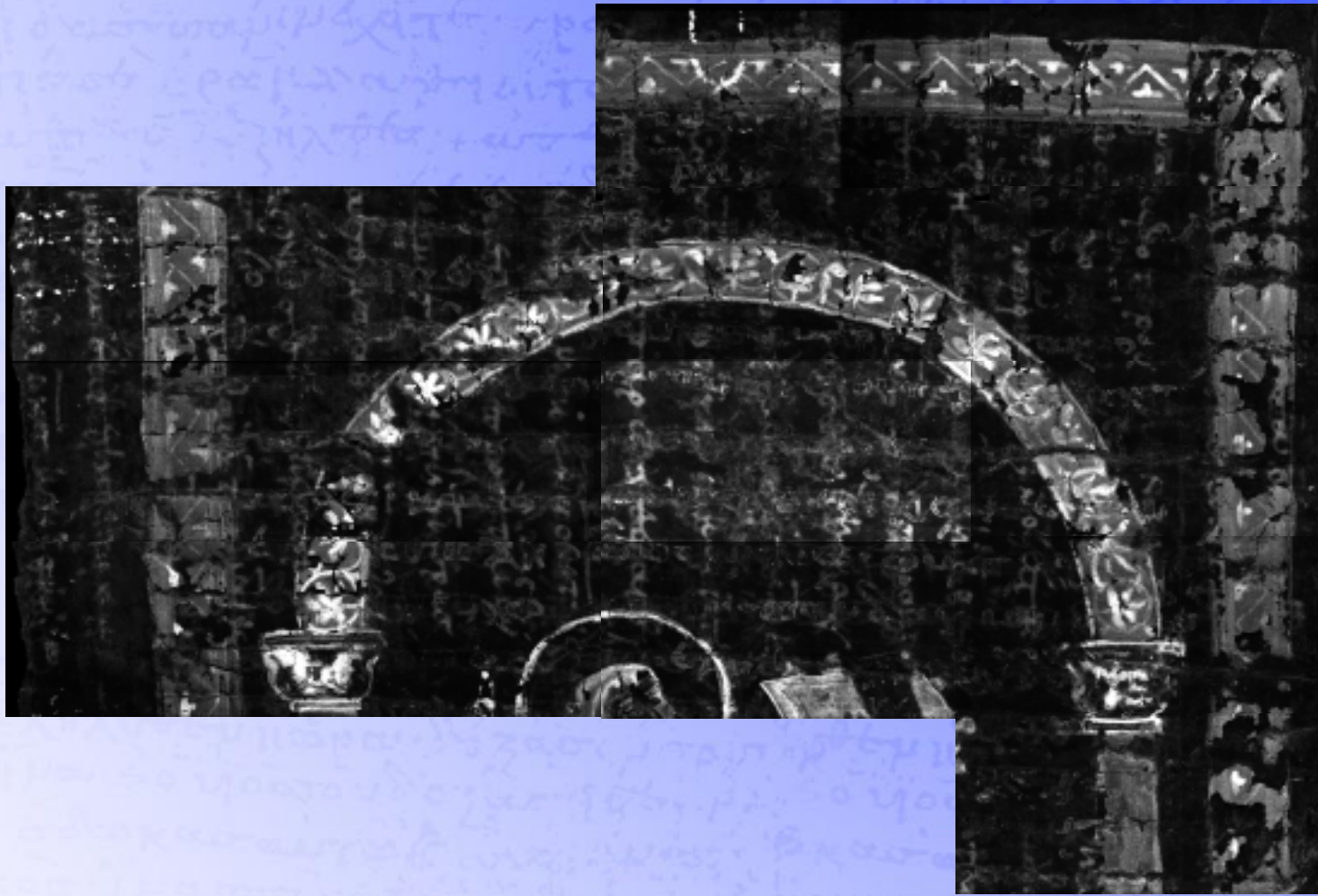
Bidirectional Continuous Scan

**SLAC is ~50X Faster Than Eagle III
(Should Be 15X)**

Elemental X-ray Area Maps

Stanford Linear Accelerator - SLAC

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Stereoview Elemental X-ray Imaging

EDAX Eagle III

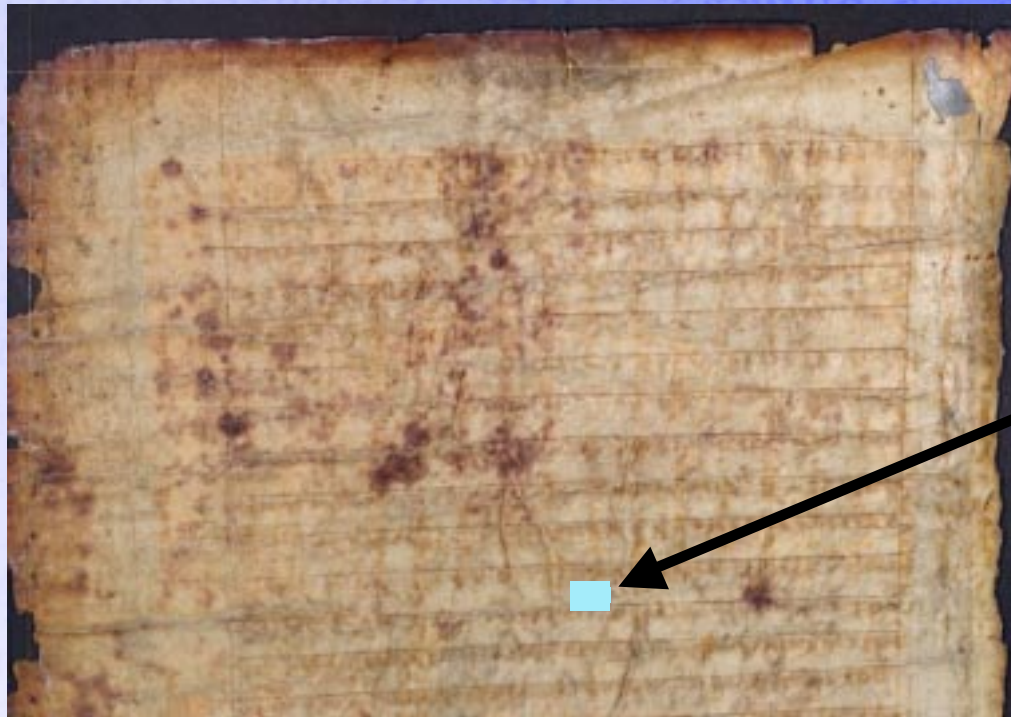
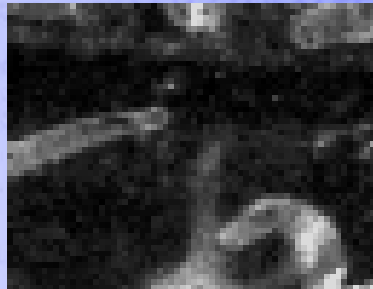


Image from the reverse side of halo in the forgery painting.

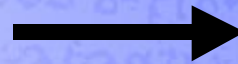
Stereoview Elemental X-ray Imaging

EDAX Eagle III

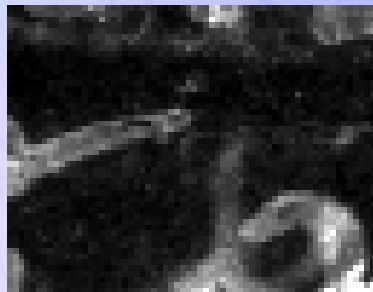
Left
Eye



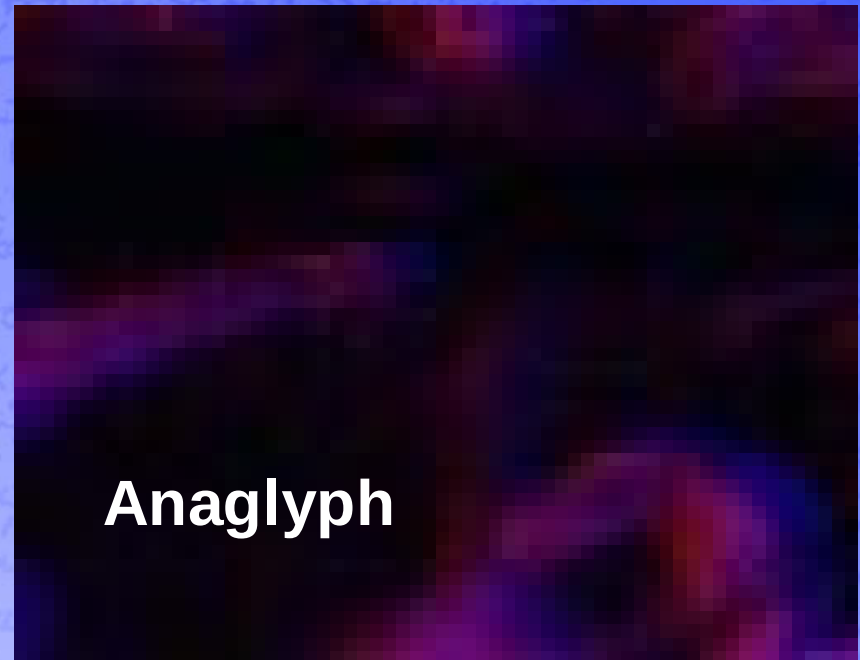
+



Right
Eye



Anaglyph



Stereoview Elemental X-ray Imaging

EDAX Eagle III

Mosaic
Photograph



Fe K- α EXAM



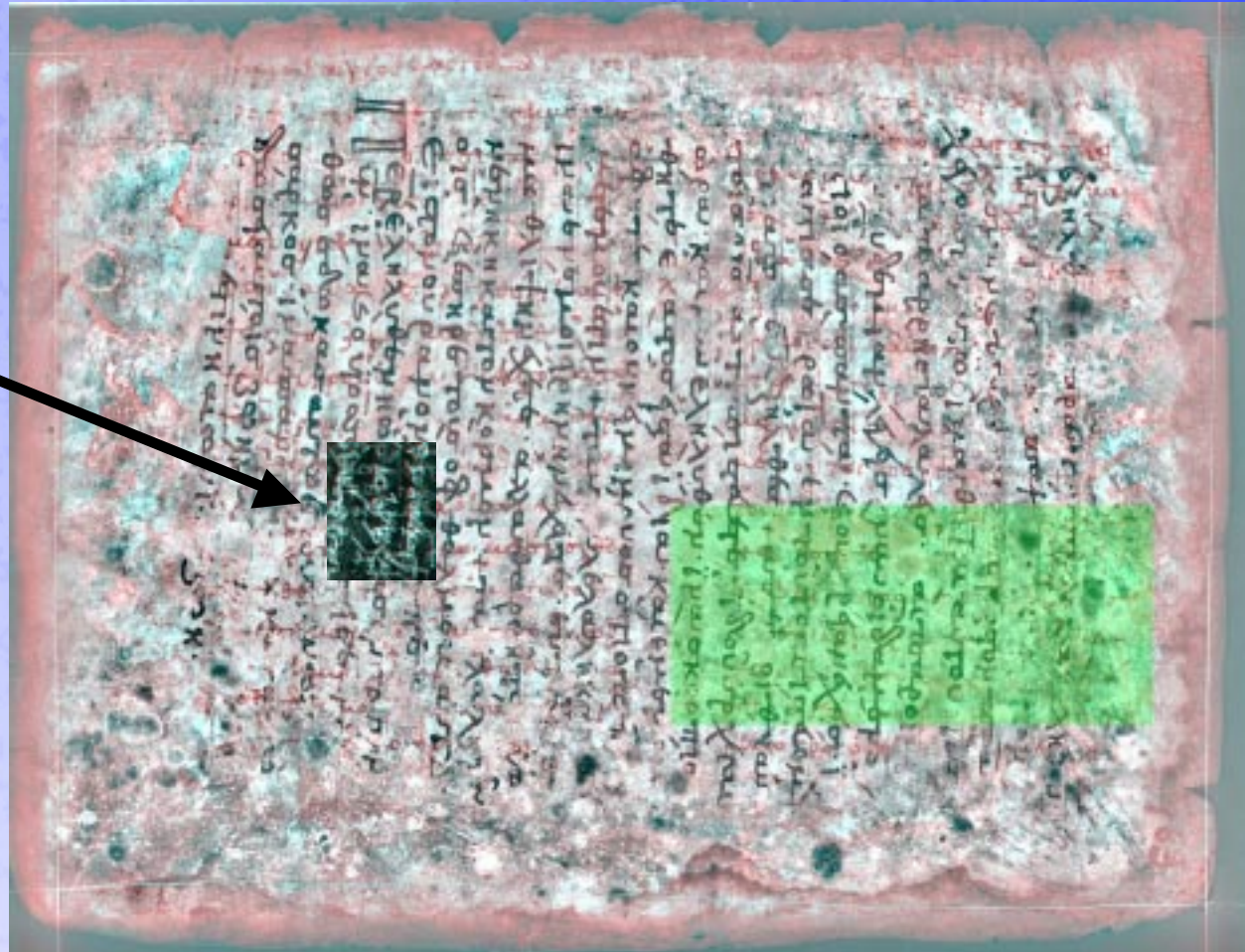
Fe K- α EXAM
Fe K- α SEXI



Stereoview Elemental X-ray Imaging

Stanford Linear Accelerator - SLAC

Region
Of Interest



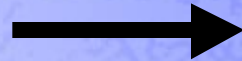
Stereoview Elemental X-ray Imaging

Stanford Linear Accelerator - SLAC

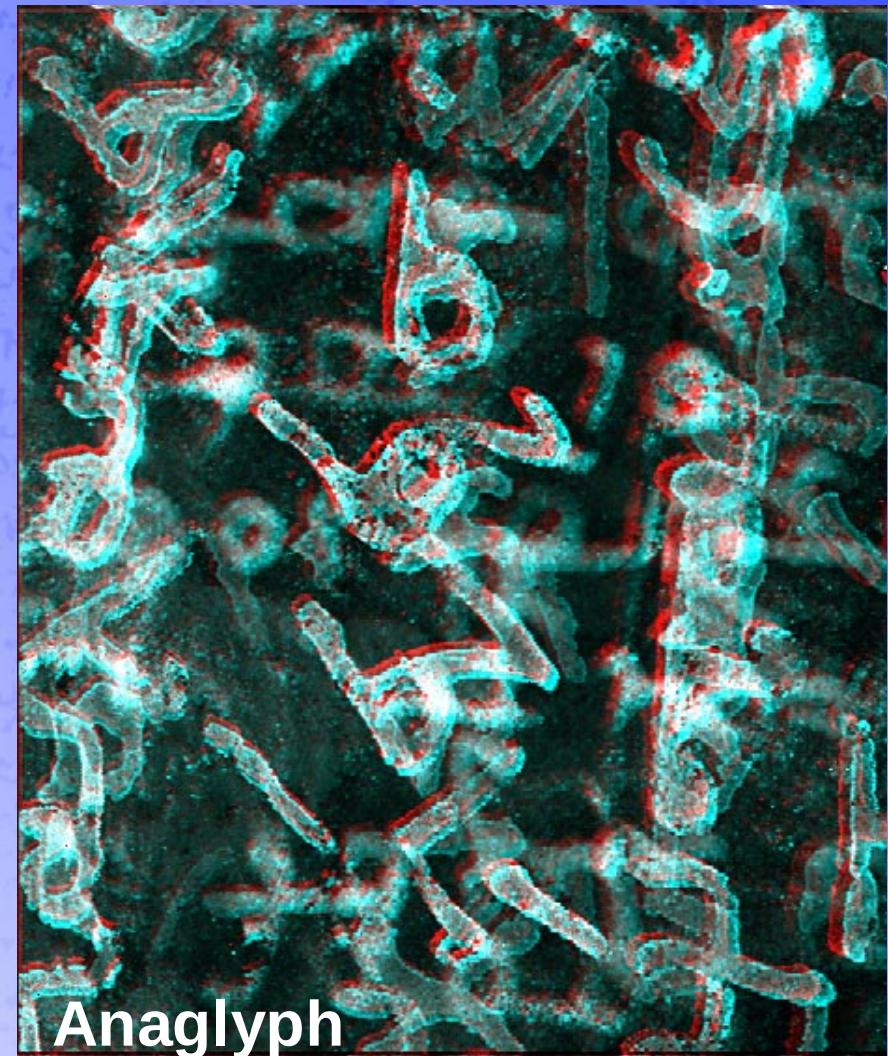
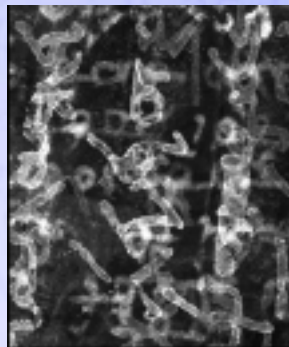
Left
Eye



+



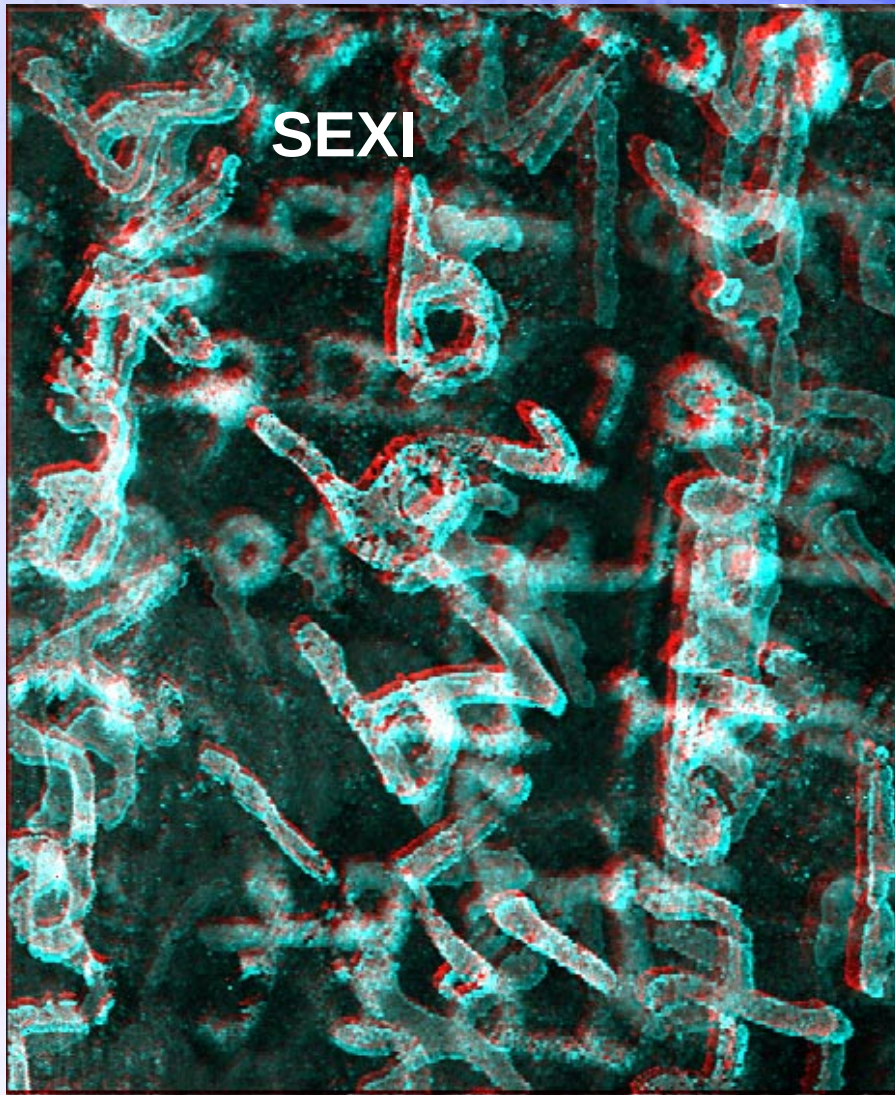
Right
Eye



Anaglyph

Stereoview Elemental X-ray Imaging

Stanford Linear Accelerator - SLAC



SEXI

- Enhances Chemical Variations
- Documents Chemical Variations
- Enhances Physical Variations
- Documents Physical Variations
- Unique Perspective to Fabrication

Summary & Conclusion

- EXAM and SEXI techniques offer a nondestructive means to image historical objects.
- EXAM and SEXI are pulse counting techniques that provide flexibility to manage imaging time.
- EXAM and SEXI are sensitive enough to bring out details within a time dependent detection limit.
- Iron gall ink can be imaged via EXAM and SEXI techniques for major and trace elements.
- EXAM is powerful enough to image through painted layers and gold leaf.
- SEXI provides perspective details to an objects fabrication history.
- SEXI helps to simplify complex images for insightful interpretation.



Acknowledgements

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Martin George – SLAC

Bruce Scruggs – EDAX

