OSHER LIFELONG LEARNING INSTITUTE

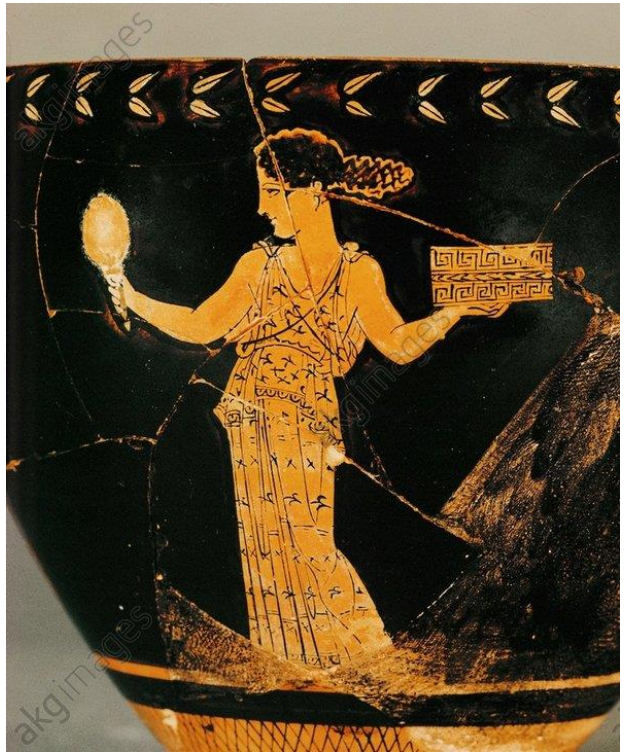
Opticks:

Optical Instruments

from Ancient Times to the Present

Woman with Mirror
Greek Vase Painting
c 420/410 BCE

(Louvre)



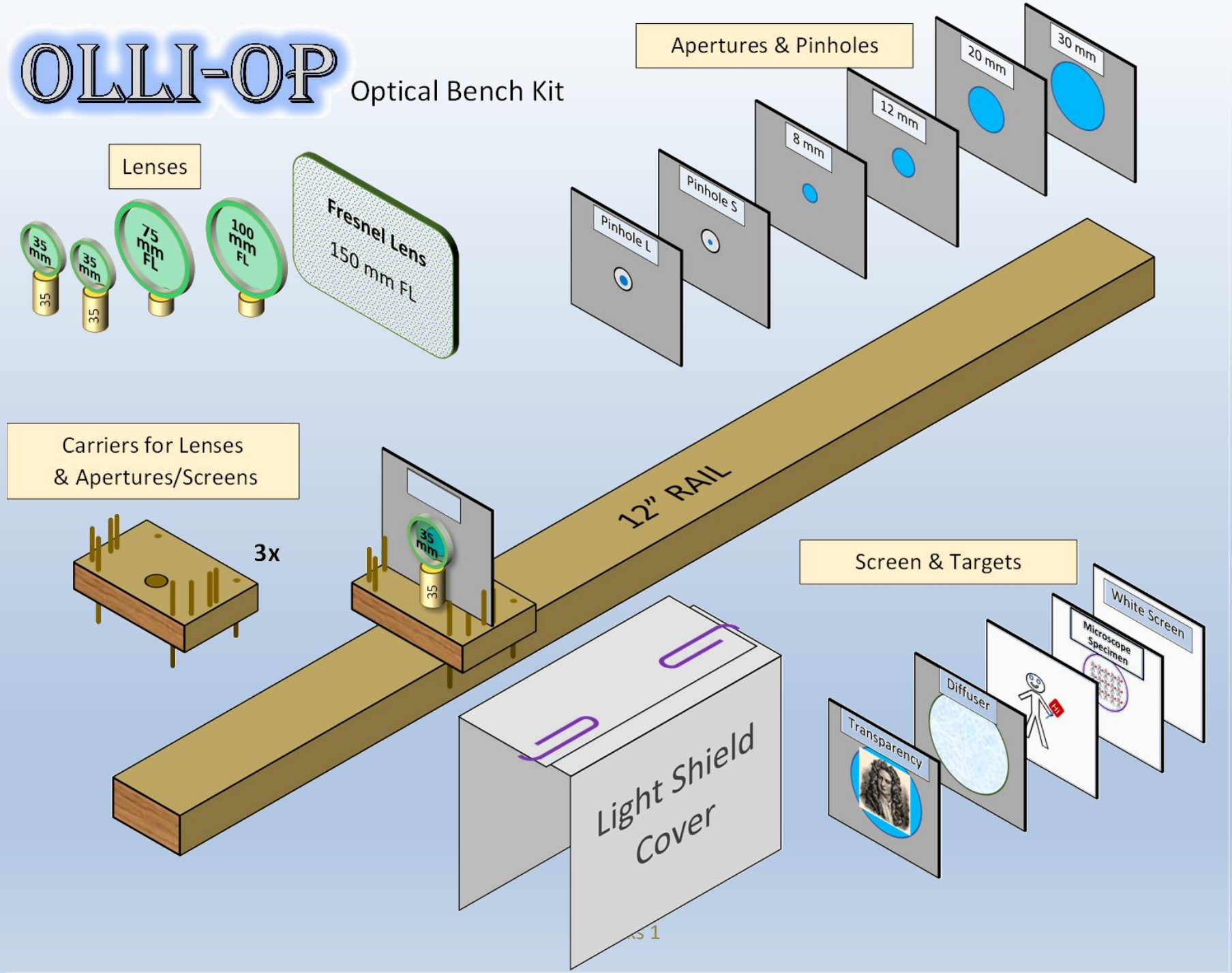
Session 1
Beginnings

OLLI at Illinois
Spring 2022

D. H. Tracy

Course Outline

1. Beginnings: Optics in the Ancient World and the Middle Ages; Mirrors and Lenses
2. Renaissance and Pre-Renaissance developments. The eye. Early telescopes & microscopes. Art and Optics.
3. Newton's contributions leading to 18th and 19th Century developments in Optical instruments.
4. Modern Optics and the methods used to design and build them. Lasers, fiberoptics, holograms, space telescopes, semiconductor lithography, gravity wave detectors, and the camera in your cell phone.


OLLI-OP
Optical Bench Kit
Lenses
35 mm
35 mm
75 mm FL
100 mm FL
Fresnel Lens
150 mm FL
Apertures & Pinholes
Pinhole L
Pinhole S
8 mm
12 mm
20 mm
30 mm
Carriers for Lenses
& Apertures/Screens
3x
12" RAIL
Light Shield
Cover
Screen & Targets
Transparency
Diffuser
Microscope
Specimen
White Screen

An early mirror

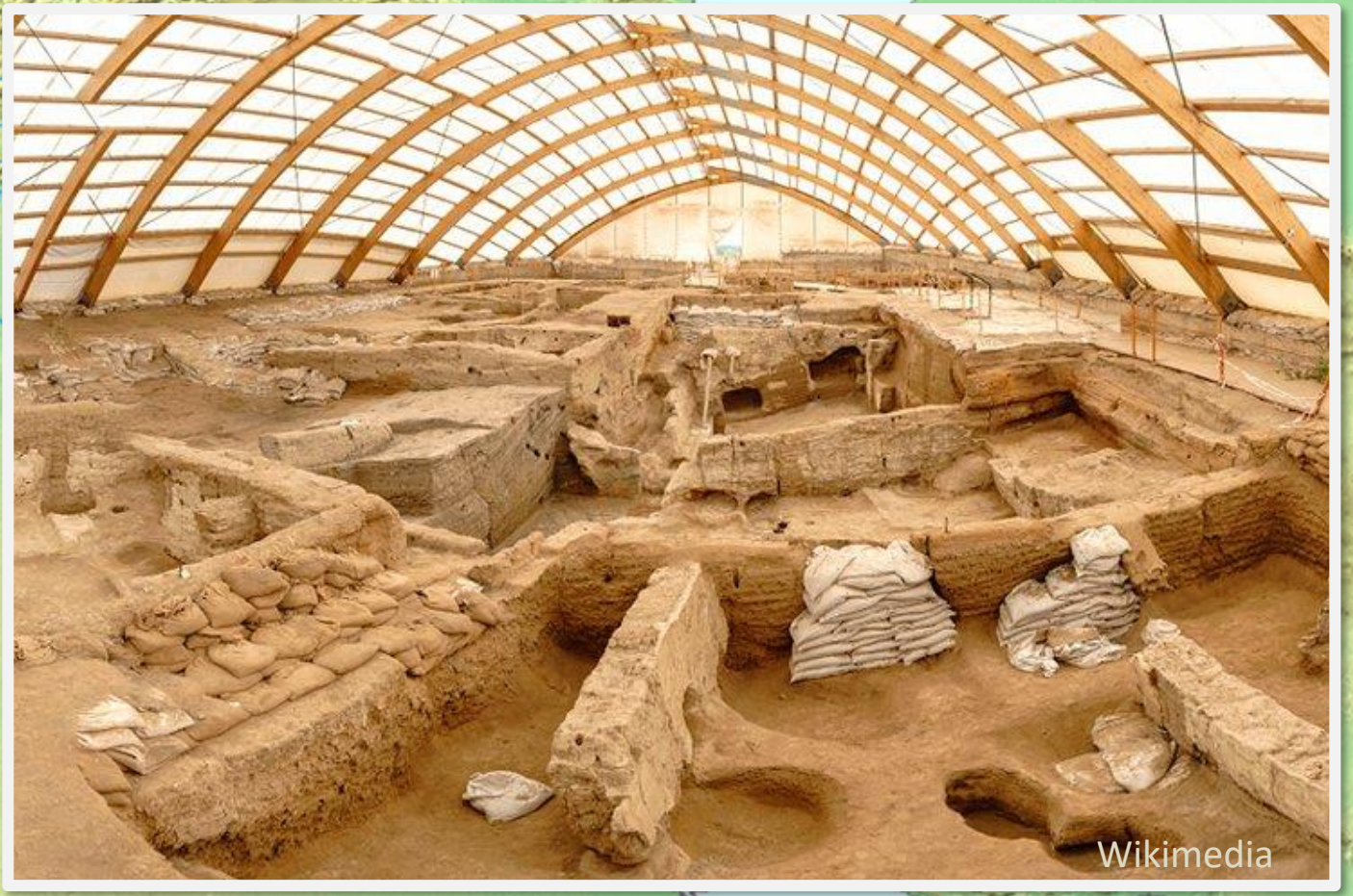
Reflectance from Water: 2%

Narcissus
Caravaggio
ca 1597

Galleria Nazionale d'Arte Antica

Anatolia

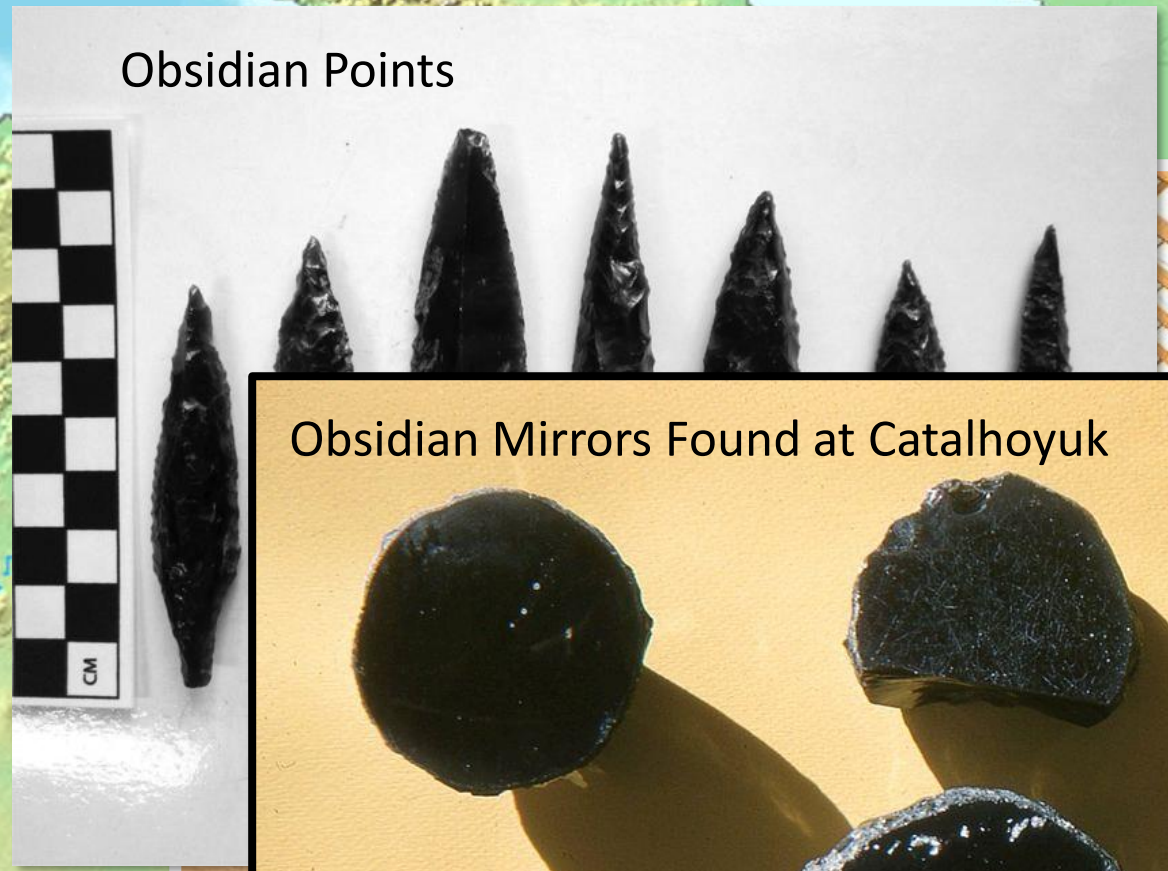
Çatalhöyük
ca 7000 BCE



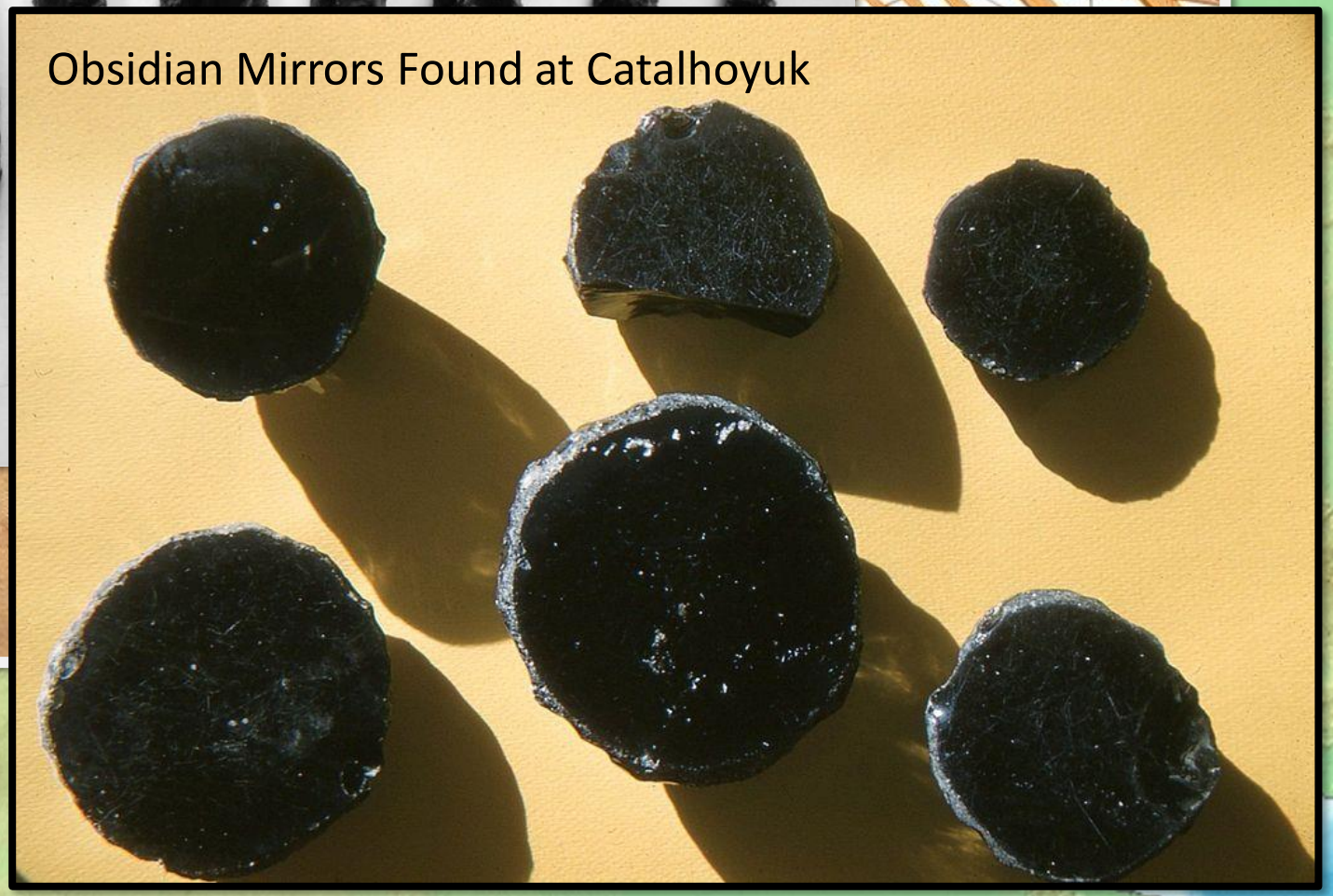
Anatolia

Çatalhöyük
ca 7000 BCE

Obsidian Points



Obsidian Mirrors Found at Catalhoyuk



Anatolia

Çatalhöyük

Typical Obsidian Raw Material

A Çatalhöyük Mirror

Catalhoyuk.com
-node-48

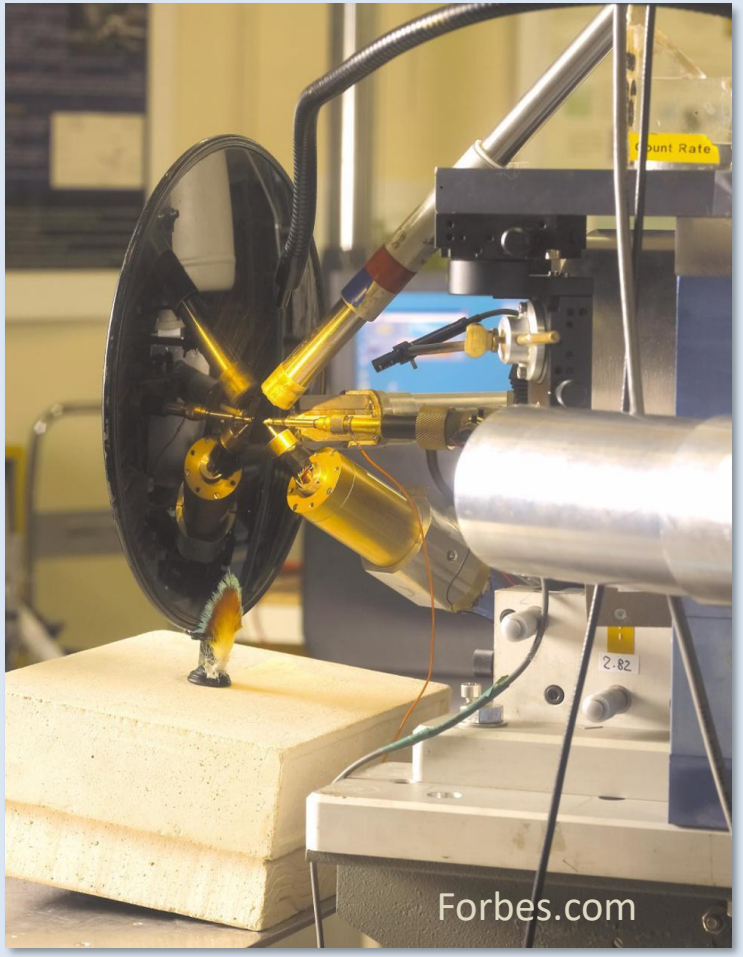
Obsidian Mirror – Unknown Provenance

Aztec Obsidian Mirror

Hematite Fe_2O_3

Timeline for Mirror Technology

Çatalhöyük
ca 7000 BCE

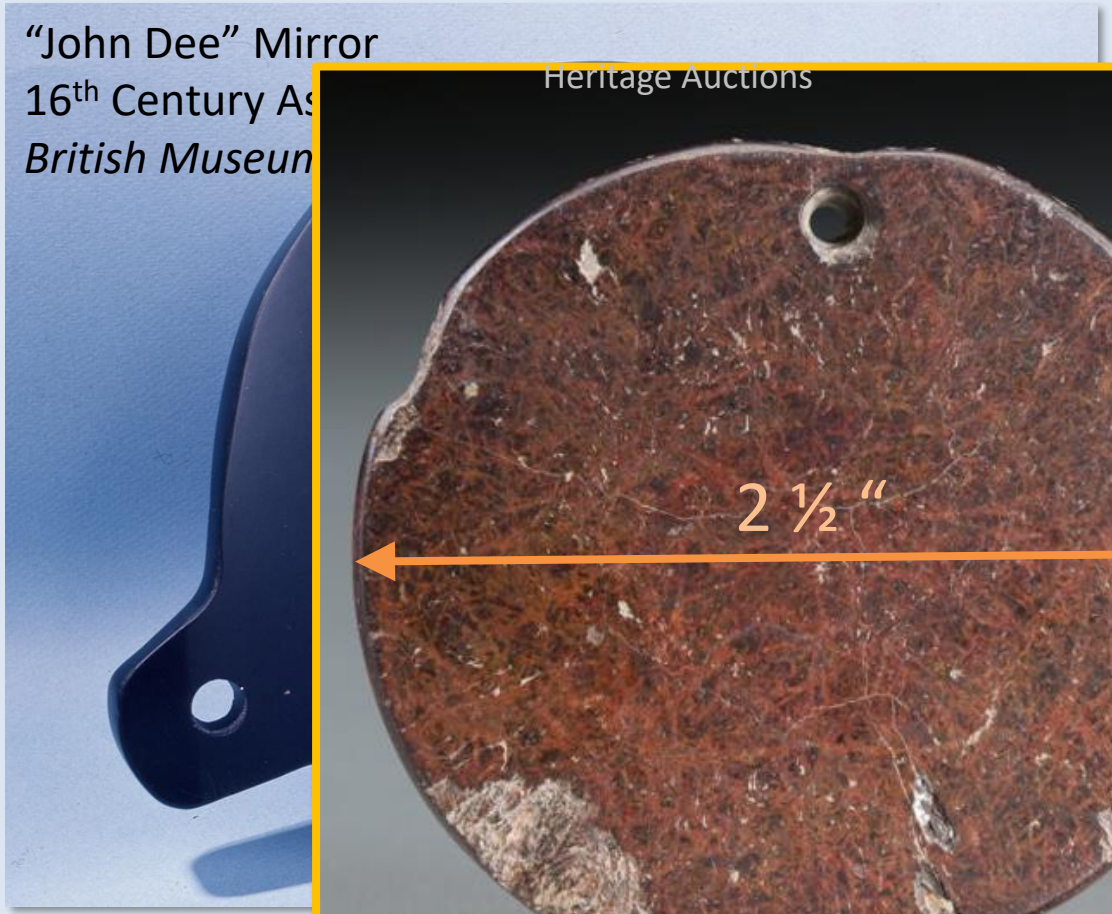


Obsidian (and other black minerals)

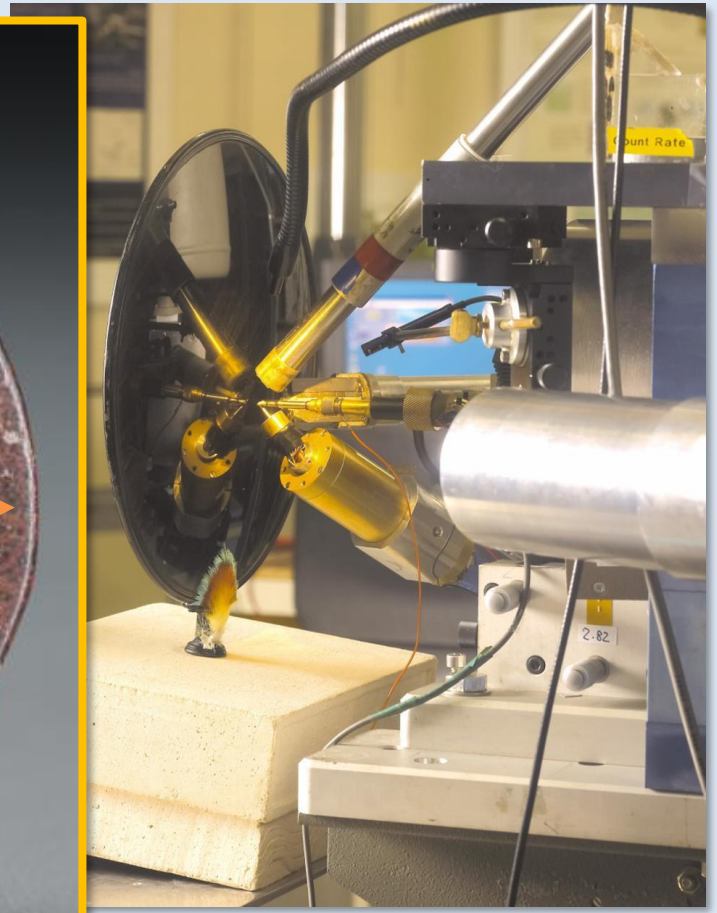
7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Timeline for Mirror Technology

Çatalhöyük
ca 7000 BCE



Chocolate Hematite Pendant Mirror
Olmec, ca 500-1000 CE



Obsidian (and other black n

7000 BCE 4000 2000 1000 500 800 2000 CE

Richard Balthazar.com

Tim

Çatalhöyük
ca 7000 BCE

Tezcatlipoca "Lord of the Night Sky"

'Smoking Mirrors'

Obsidian (and other black mine

7000 BCE 4000 2000 1000 500 2000 CE

Timeline for Mirror Technology

Çatalhöyük
ca 7000 BCE

Olmec
ca 500 CE

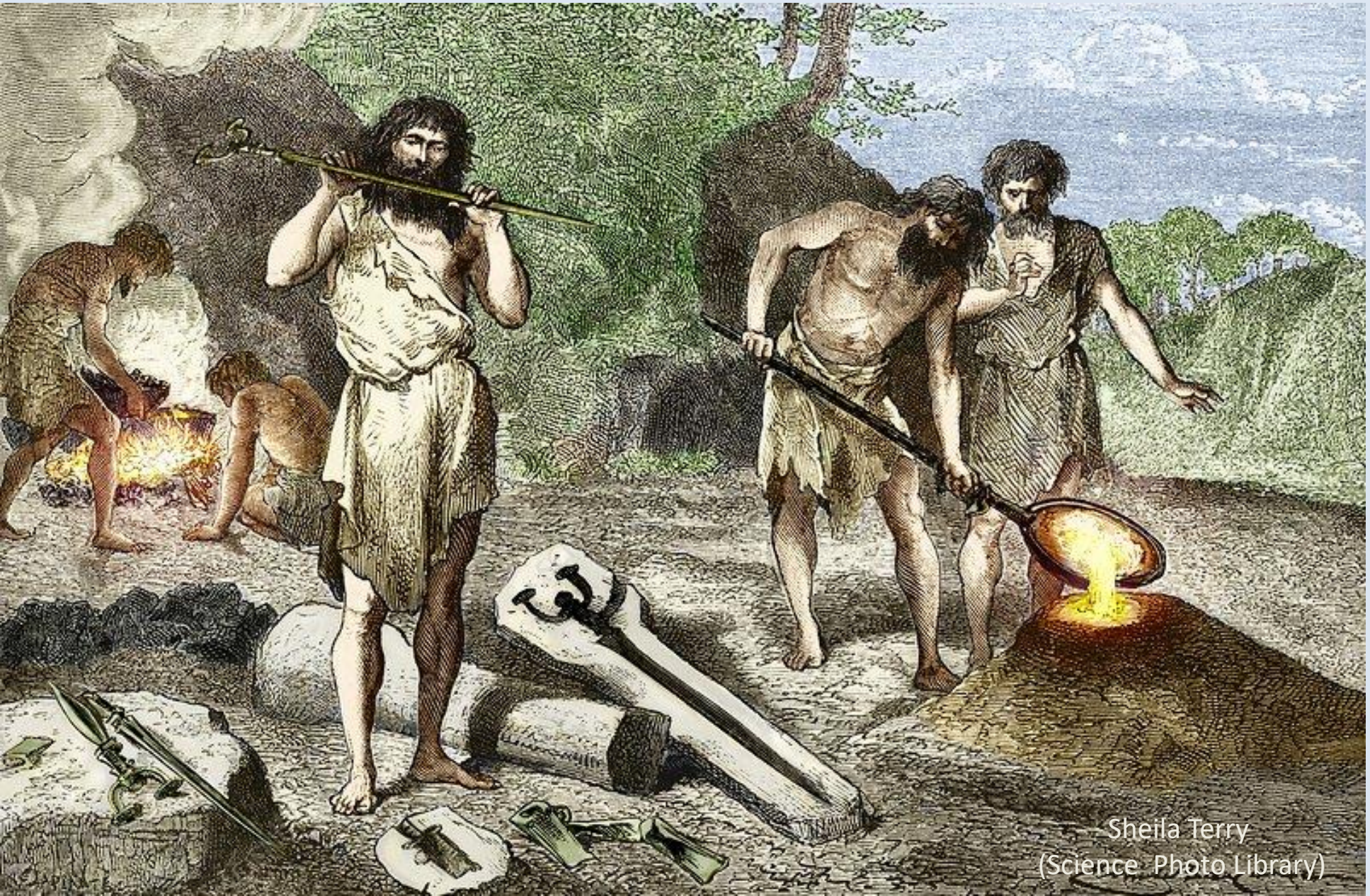
Aztec

Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Richard Balthazar.com

The Bronze Age Begins *ca* 3000 BCE



Smelting Ores of Copper, Tin and (later) Lead

Timeline for Mirror Technology

Around 3000 BCE the Bronze Age Begins

Çatalhöyük
ca 7000 BCE

Bronze (also Silver & Speculum)

Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

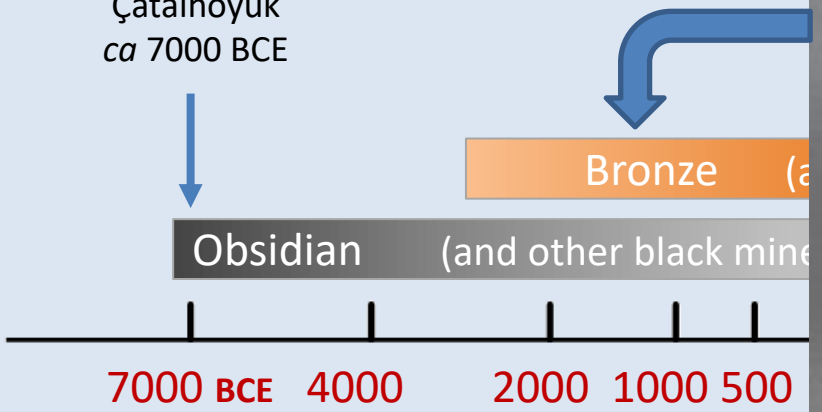
Tin

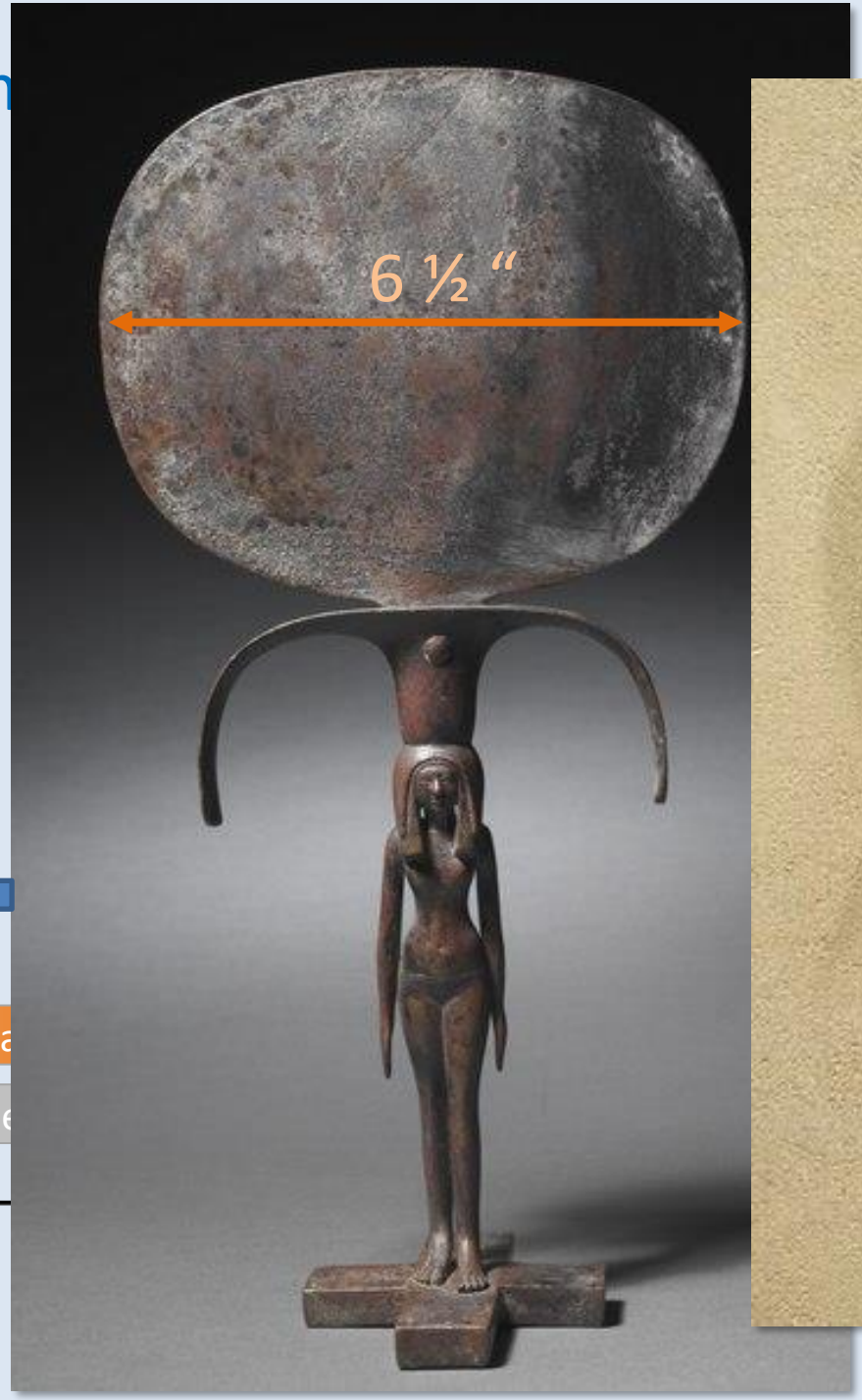
Over 100 Bronze Mirrors found in Egyptian Tombs.

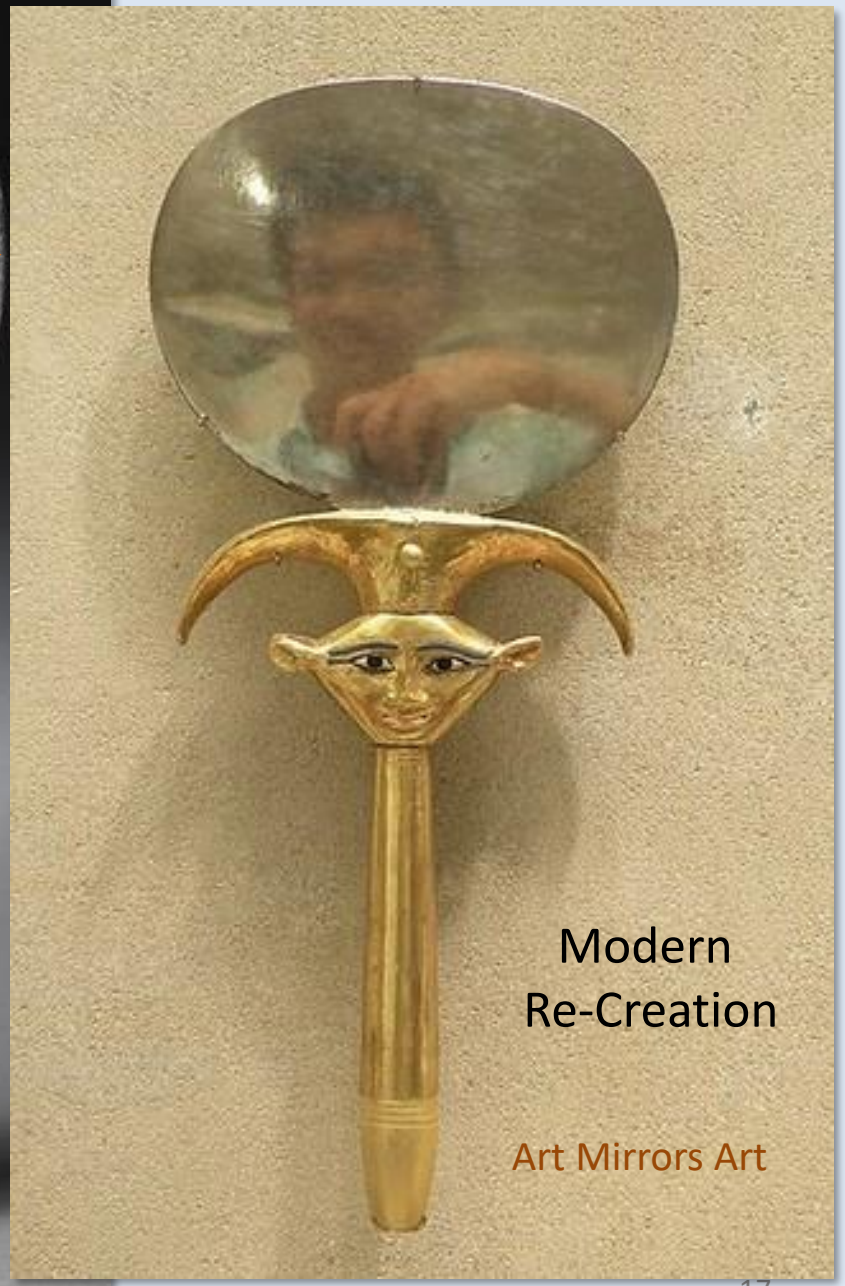
Example:

Caryatid Mirror
New Kingdom, 18th Dynasty
ca 1540-1296 BCE
(Cleveland Museum of Art)

Çatalhöyük
ca 7000 BCE



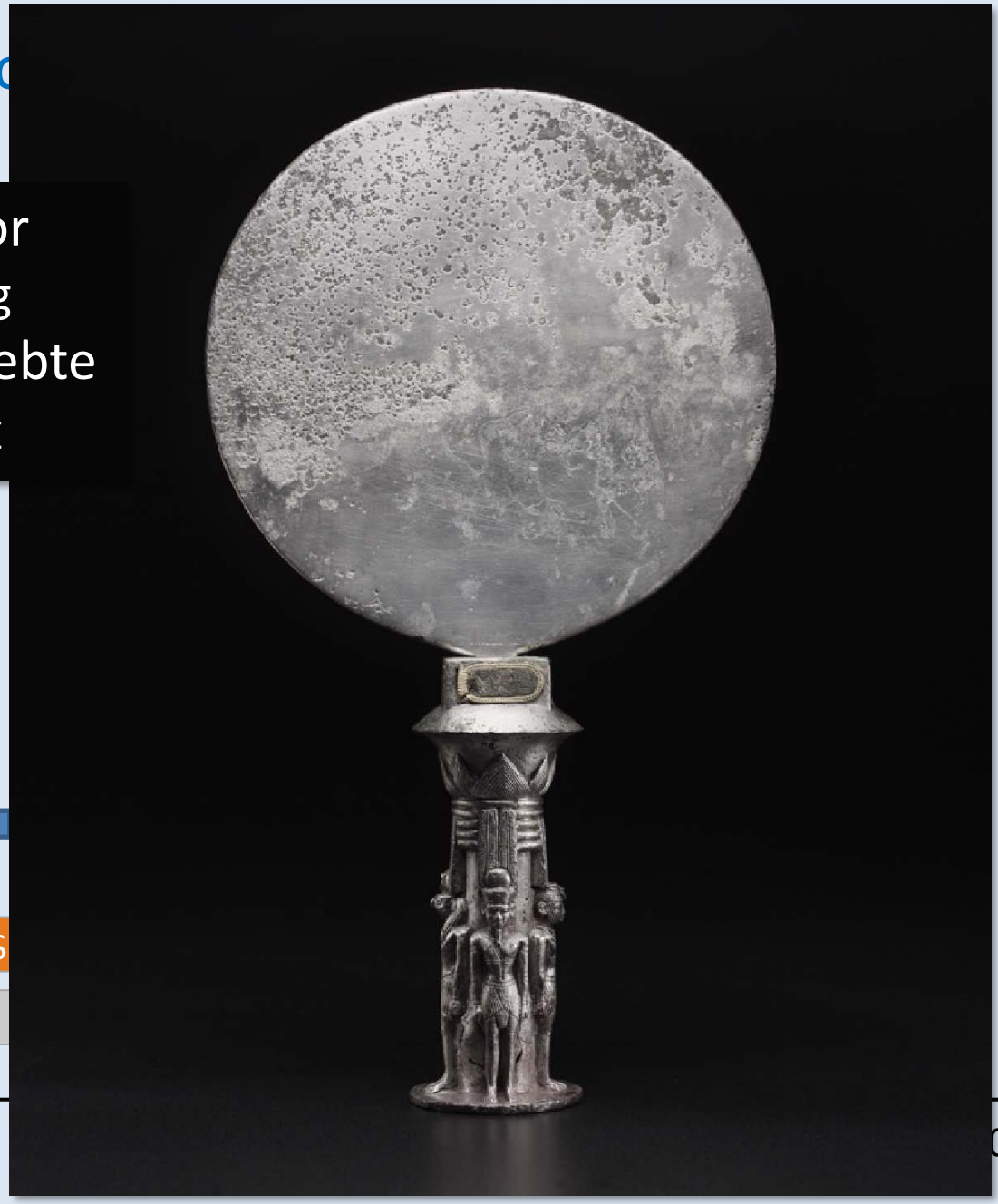




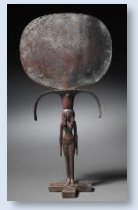
Timeline fo

Over 100 Bronze Mirrors found in Egyptian Tombs.

Silver Mirror
Nubian King
Amaninatakelebte
538-510 BCE



Çatalhöyük
ca 7000 BCE



Egypt 18th Dynasty
~1400 BCE

Bronze (also Silver & S

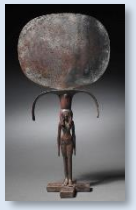
Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500 00 CE

Timeline fo

Mirrors spilled over to Greece

Çatalhöyük
ca 7000 BCE



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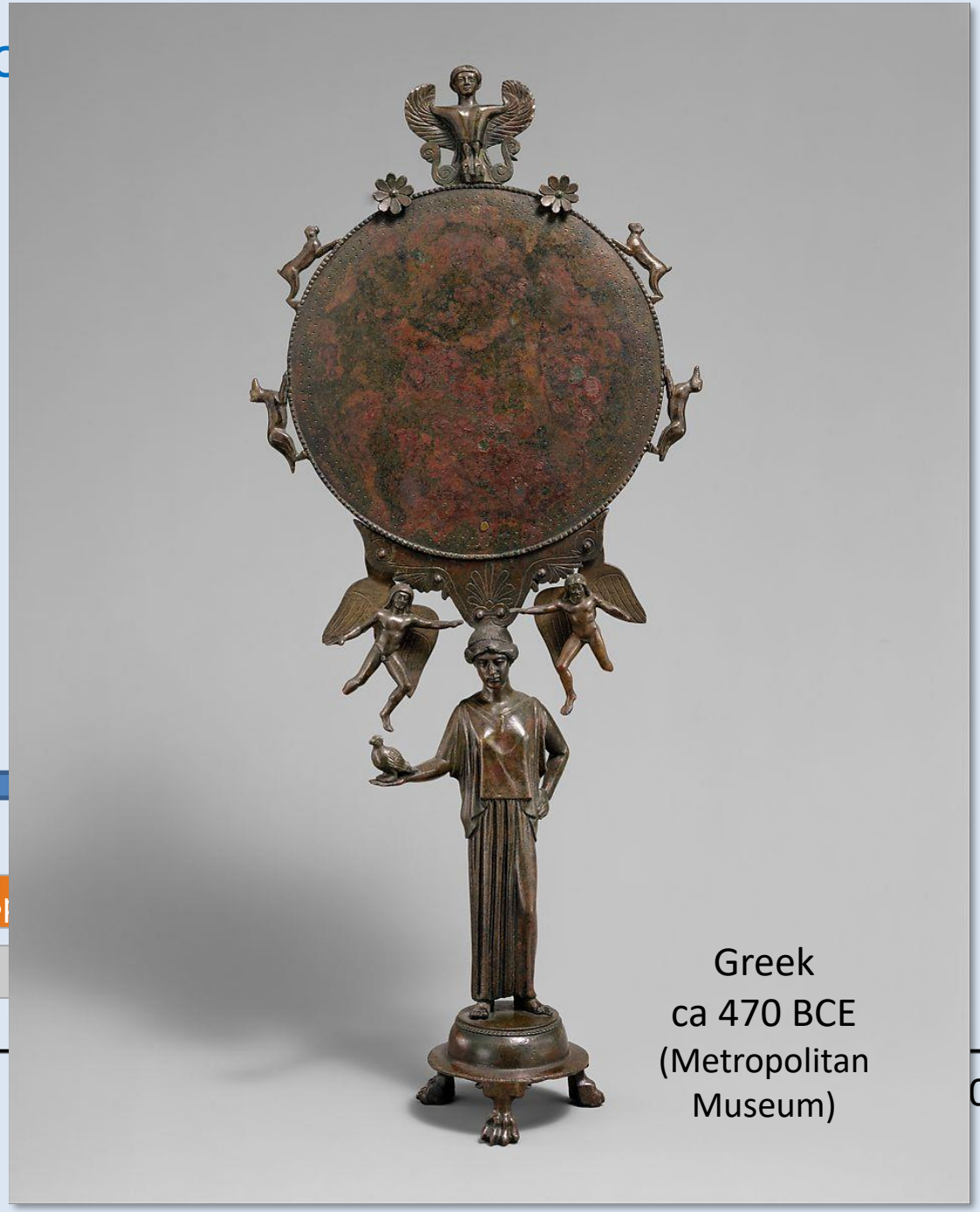
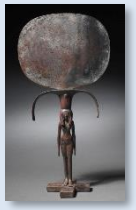


Greek
ca 470 BCE
(Metropolitan Museum)

Timeline

Mirrors spilled over to Greece

Çatalhöyük
ca 7000 BCE



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Bronze (also Silver

Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500

Greek
ca 470 BCE
(Metropolitan Museum)

Mirrors spilled over to Greece

Çatalhöyük
ca 7000 BCE

Egy

Obsidian (and

7000 BCE 4000 20

00

Front View

Greek
5th BCE
(Metropolitan Museum)

Rear View

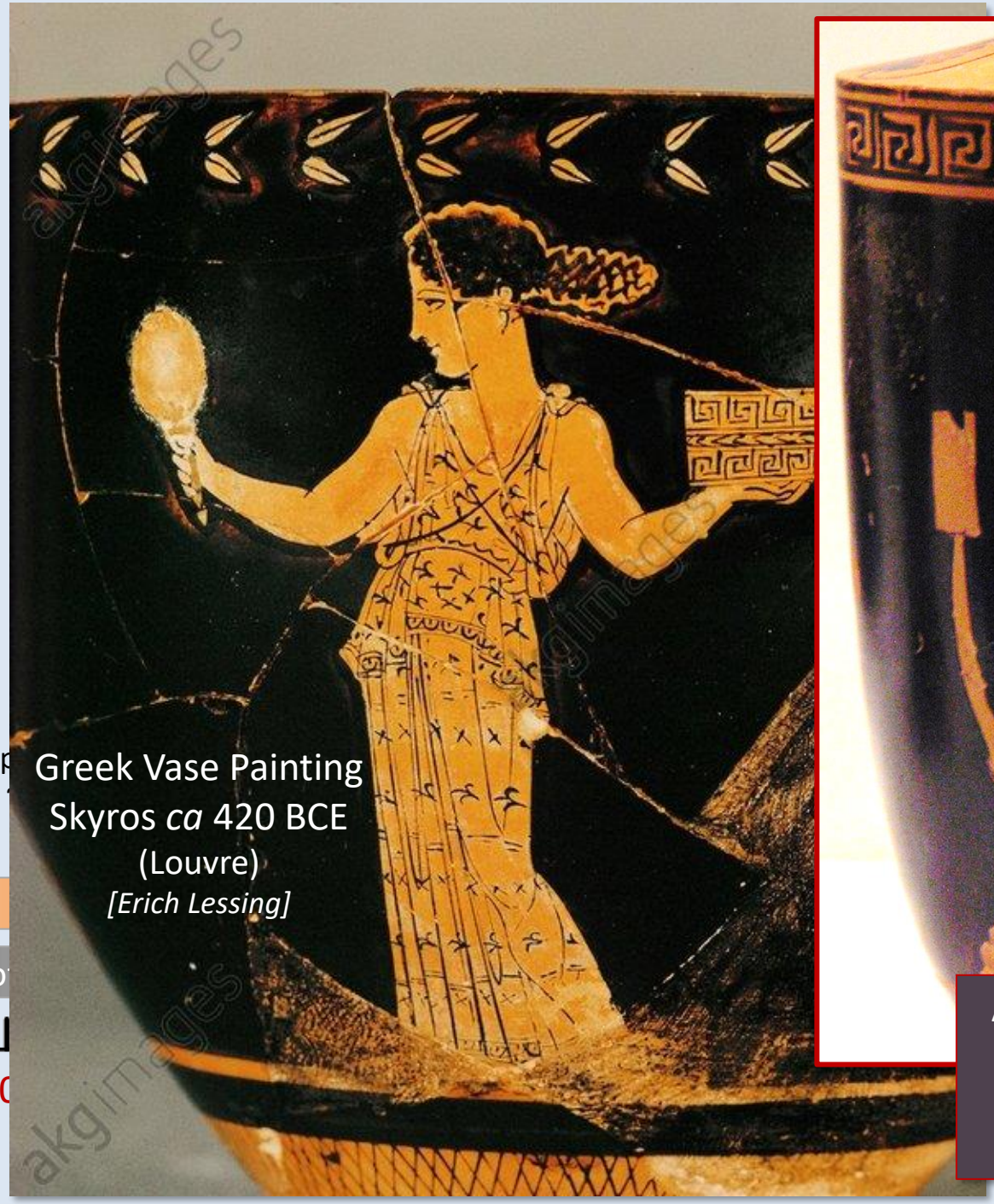
Mirrors spilled over to Greece … and they were actually used

Çatalhöyük
ca 7000 BCE

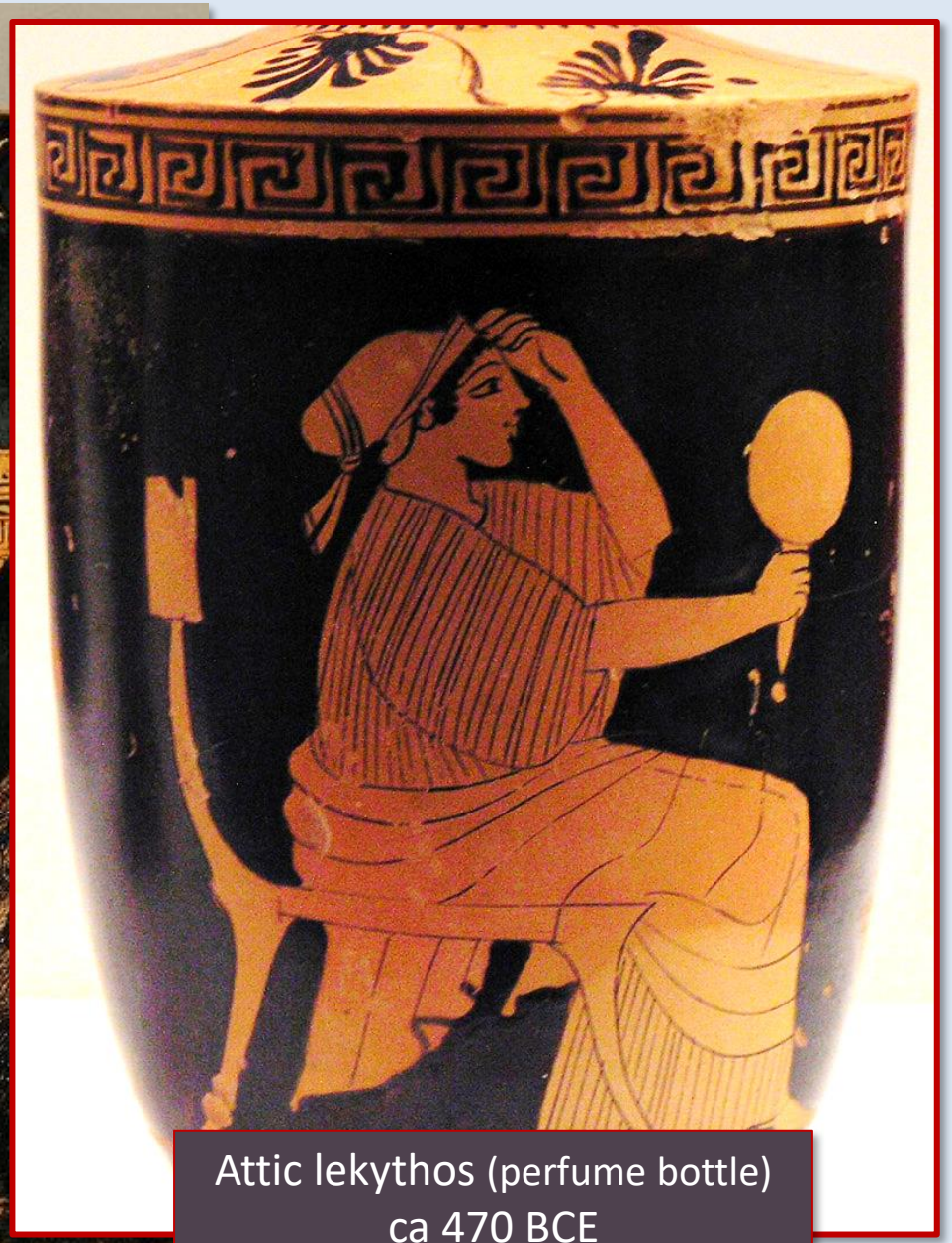
Egyp

Obsidian (and o

7000 BCE 4000 200



Greek Vase Painting
Skyros *ca* 420 BCE
(Louvre)
[Erich Lessing]

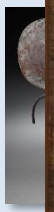


Attic lekythos (perfume bottle)
ca 470 BCE
(National Archaeol. Museum Athens)
[WikiMedia]

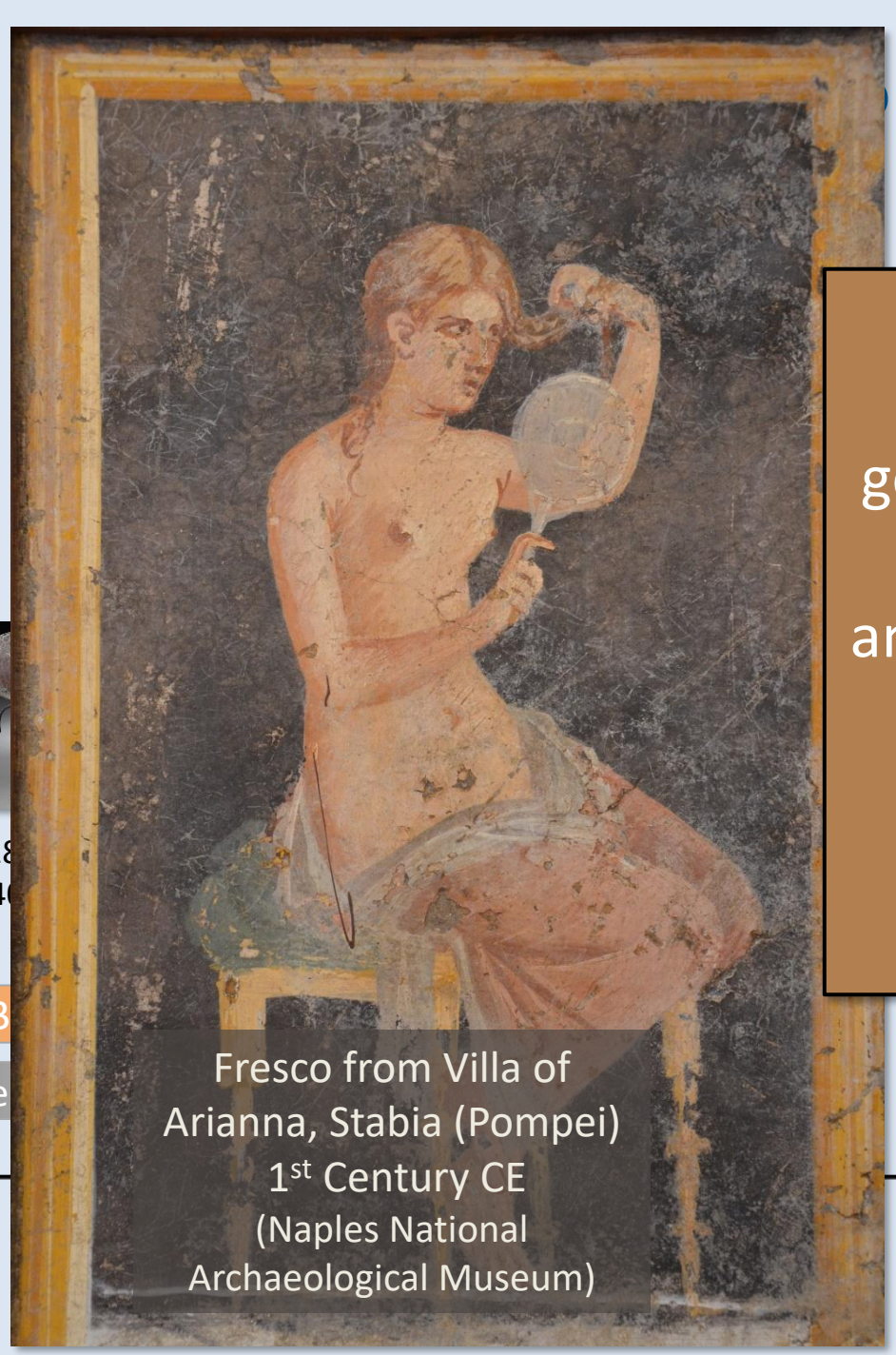
ology

Bronze mirrors were even more common in Roman households

Çatalhöyük
ca 7000 BCE



Egypt 18
~14



Fresco from Villa of Arianna, Stabia (Pompei)
1st Century CE
(Naples National Archaeological Museum)

"For a single one of these mirrors of chiseled silver or gold, inlaid with gems, women are capable of spending an amount equal to the dowry the State once offered to poor generals' daughters!"
Seneca,
Naturales quaestiones (ca 65 CE)

B

Obsidian (and othe

7000 BCE 4000 2000 1800 2000 CE

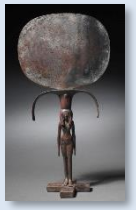
Timeline for Mirror Technology

When did *glass* mirrors appear?

Pliny the Elder
23-79 CE
Naturalis Historia

Vague suggestions that small glass mirrors with lead or gold reflecting surfaces were being made in Lebanon…

Çatalhöyük
ca 7000 BCE



Egypt 18th Dynasty
~1400 BCE

First archaeological evidence of **glass mirrors** dates from *ca* 3rd Century CE

Bronze (also Silver & Speculum)

Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Timeline for Mirror Technology

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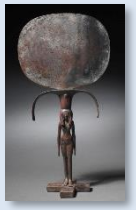
ca 7000 BCE



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~1400 BCE

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Glass (with metallic coating)

Bronze (also Silver & Speculum)

Obsidian (and other black minerals)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Rembrandt's
Apostle Paul

For now we see **through a glass darkly**….

1 Corinthians 13: 12-13 (*ca* **54 CE**)
King James Version 1611

βλέπομεν γὰρ ἄρτι δι' ἐσόπτρου ἐν αἰνίγματι …

For we see now in a mirror obscurely…

Andy Meeson

Paul is almost certainly referring to a
metal mirror

How were early glass mirrors made?

1. Make a pot of molten glass

Illuminated miniature from manuscript of H. Maurus, *De Universo* (1023 CE)

SiO_2 + Na_2O

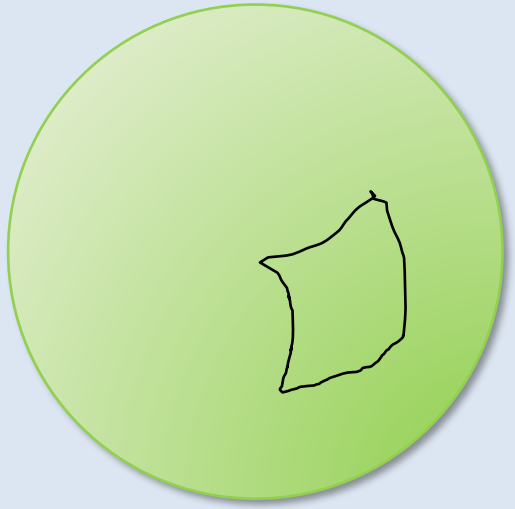
Quartz Sand Soda Ash

Woodcut illustration from G. Agricola *De Re Metallica* (1556)

How were early glass mirrors made?

1. Make a pot of molten glass
2. Blow a spherical bubble

3. Cut out a convex piece



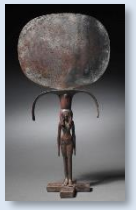
4. Add metal to inner surface

(Photo from AncientResource.com)

Timeline for Mirror Techno

Venice moves all glassworks to Murano (1292)

Çatalhöyük *ca* 7000 BCE



Egypt 18th Dynasty ~1400 BCE

Glass (with metallic coating)

Bronze (also Silver & Speculum)

Obsidian (and other black minerals)

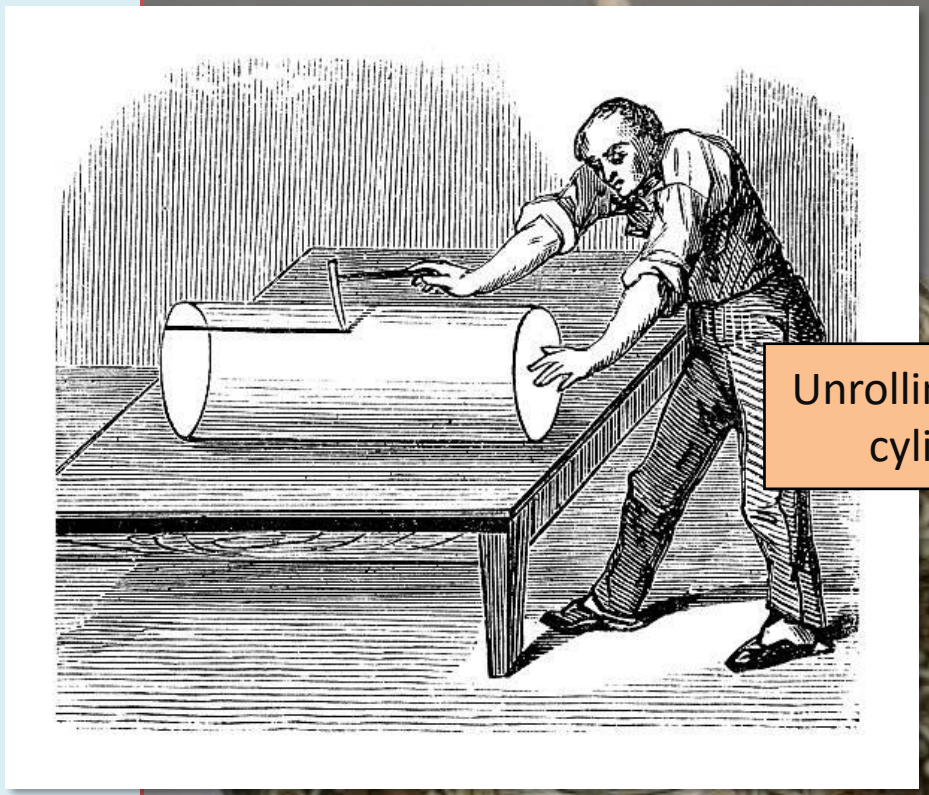
7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Early Glass Mirrors were Convex

‘A Goldsmith in His Shop’ Petrus Christus (1449)

Venetian Mirrors of 15th Century

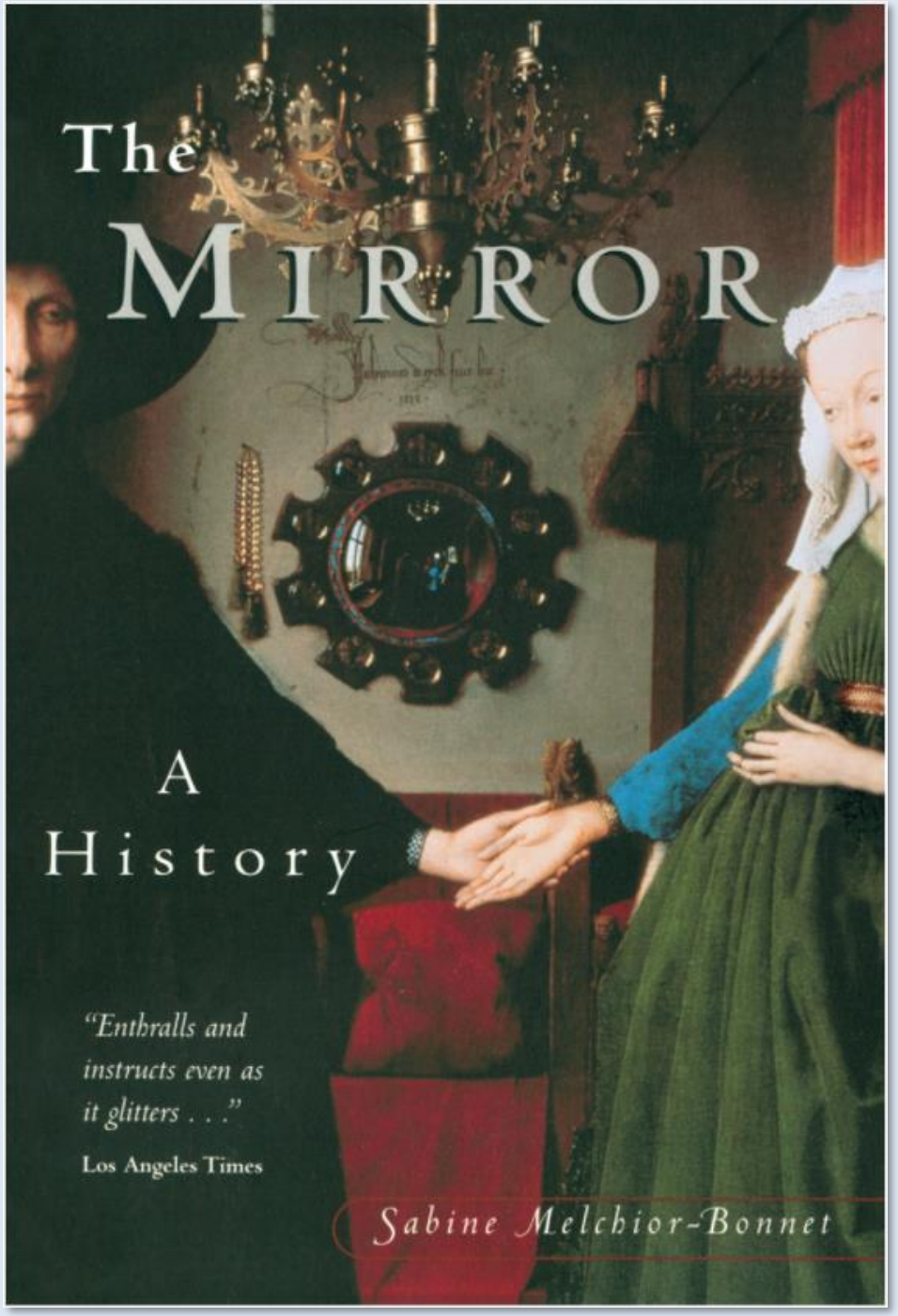
Venetian Mirrors of 15th Century



Unrolling blown cylinder

Keys to Venice's Success:

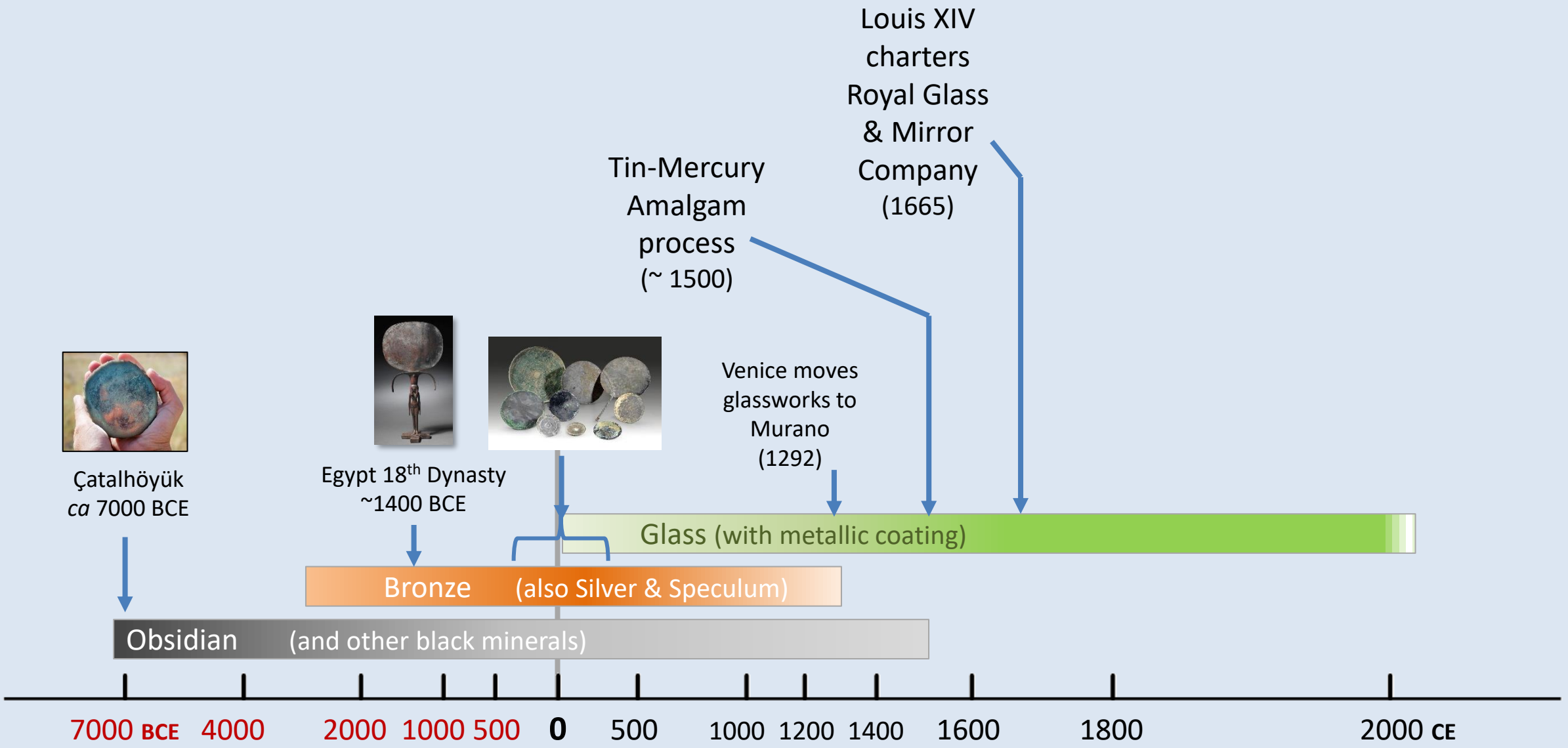
1. Development of very clear glass — "Cristallo"
2. Techniques for flattening glass in increasing sizes
3. Improved metallization – Tin Amalgam ("tain") — Flemish invention
4. Artistry and Craftsmanship
5. Draconian secrecy

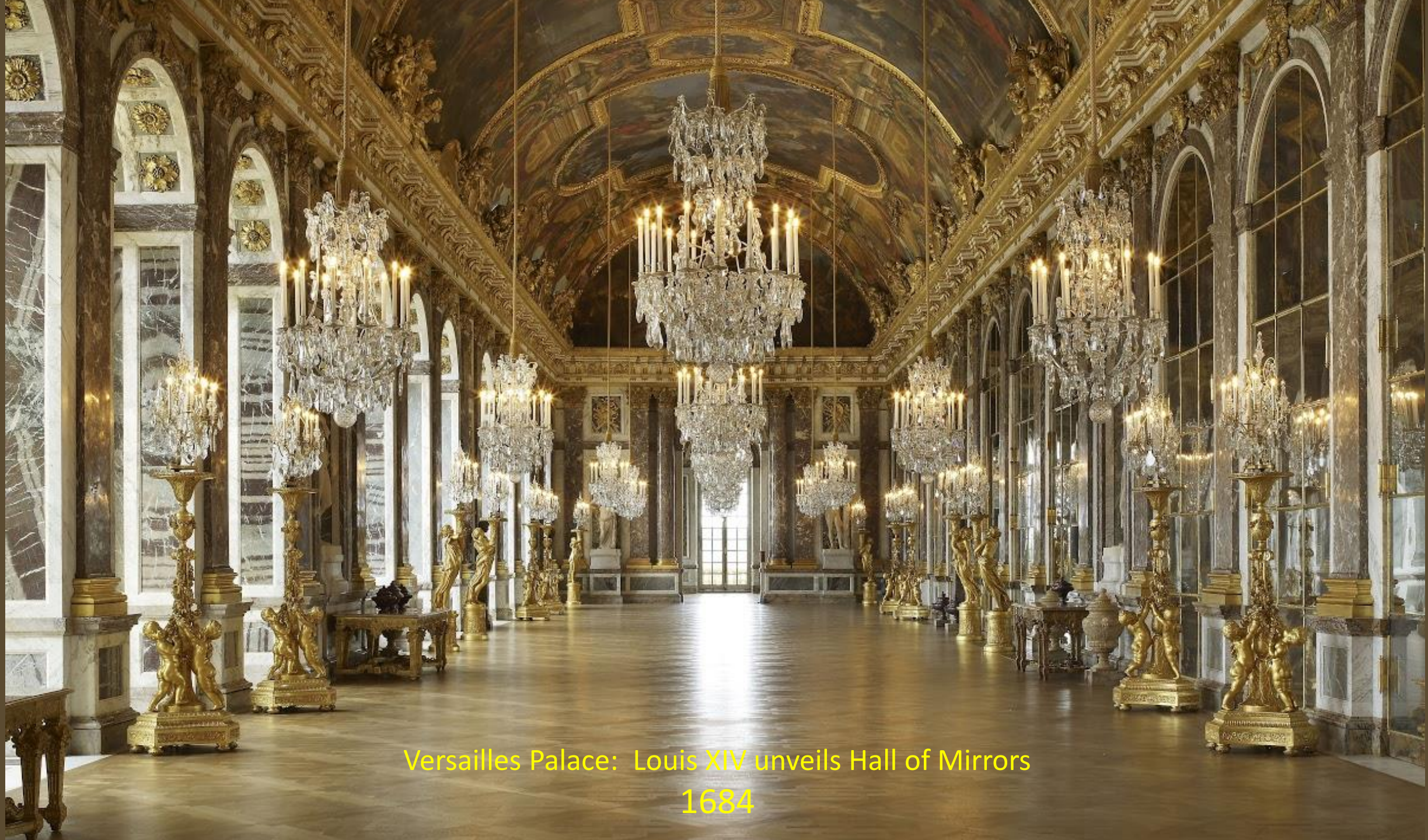


The Mirror: A History
Sabine Melchior-Bonnet
(1994)
English translation 2001, Routledge

Especially good on the industrial espionage and economic battle over mirrors between Venice and France in the 17th century.

Timeline for Mirror Technology





Versailles Palace: Louis XIV unveils Hall of Mirrors
1684

Timeline for Mirror Technology

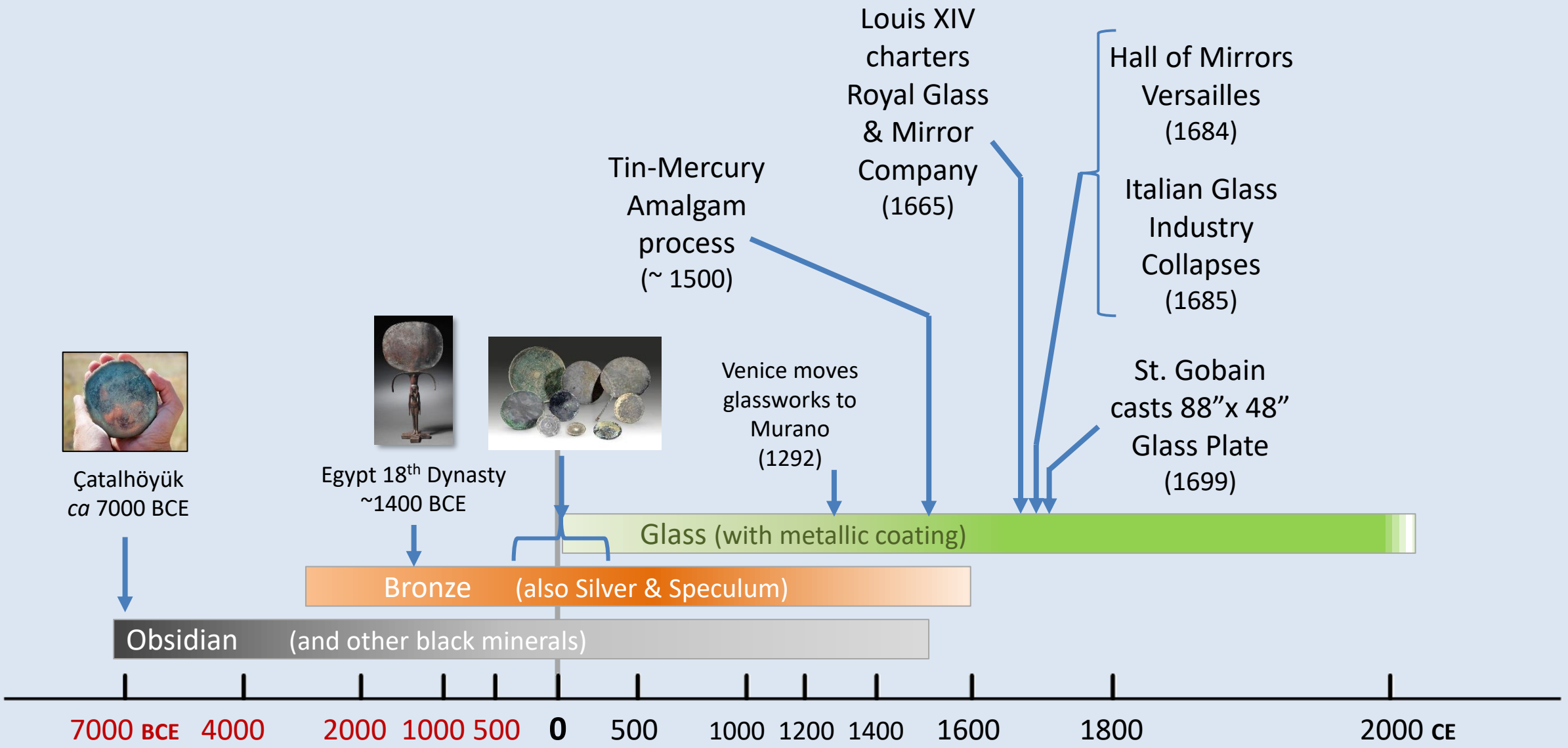
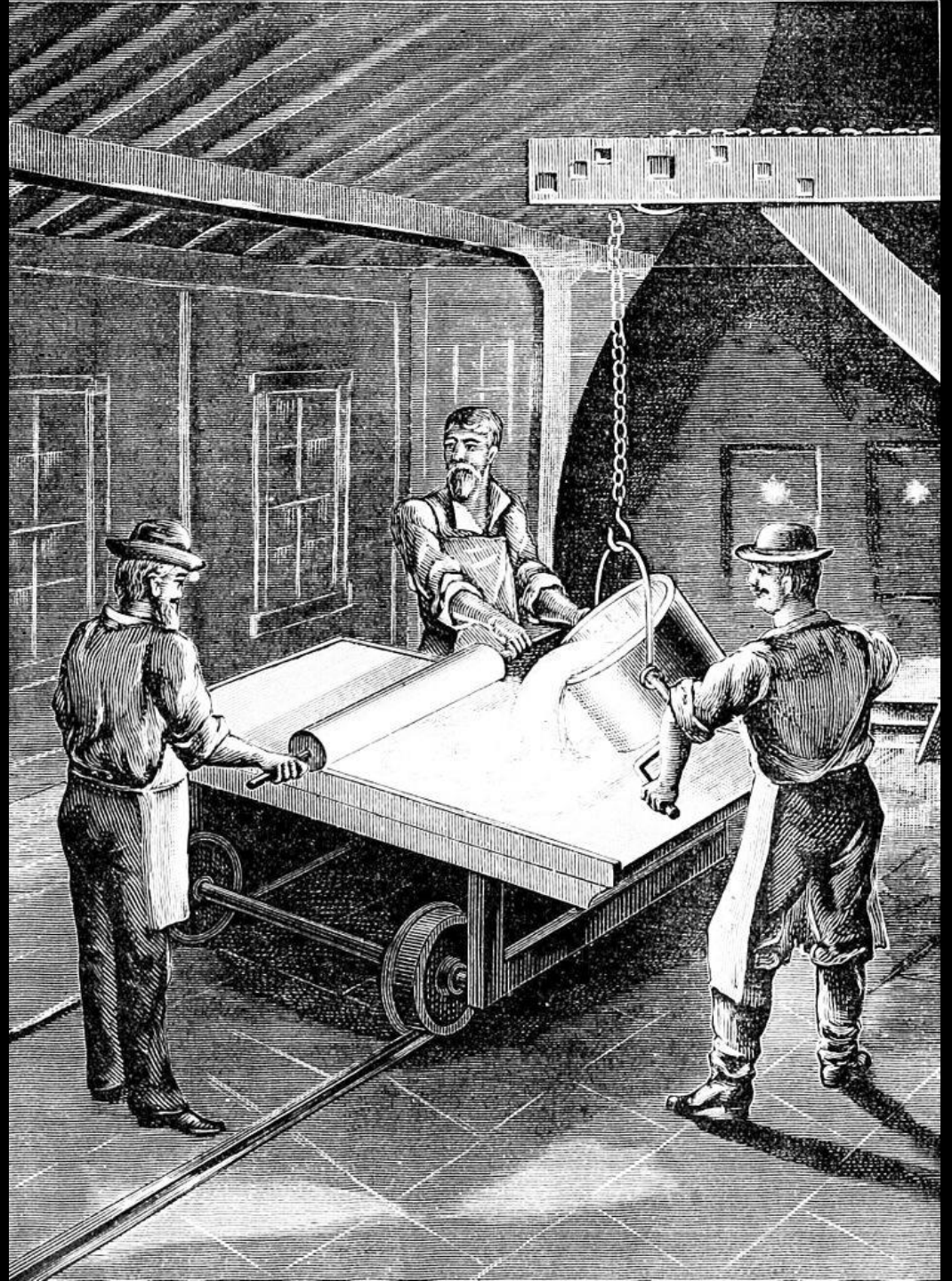
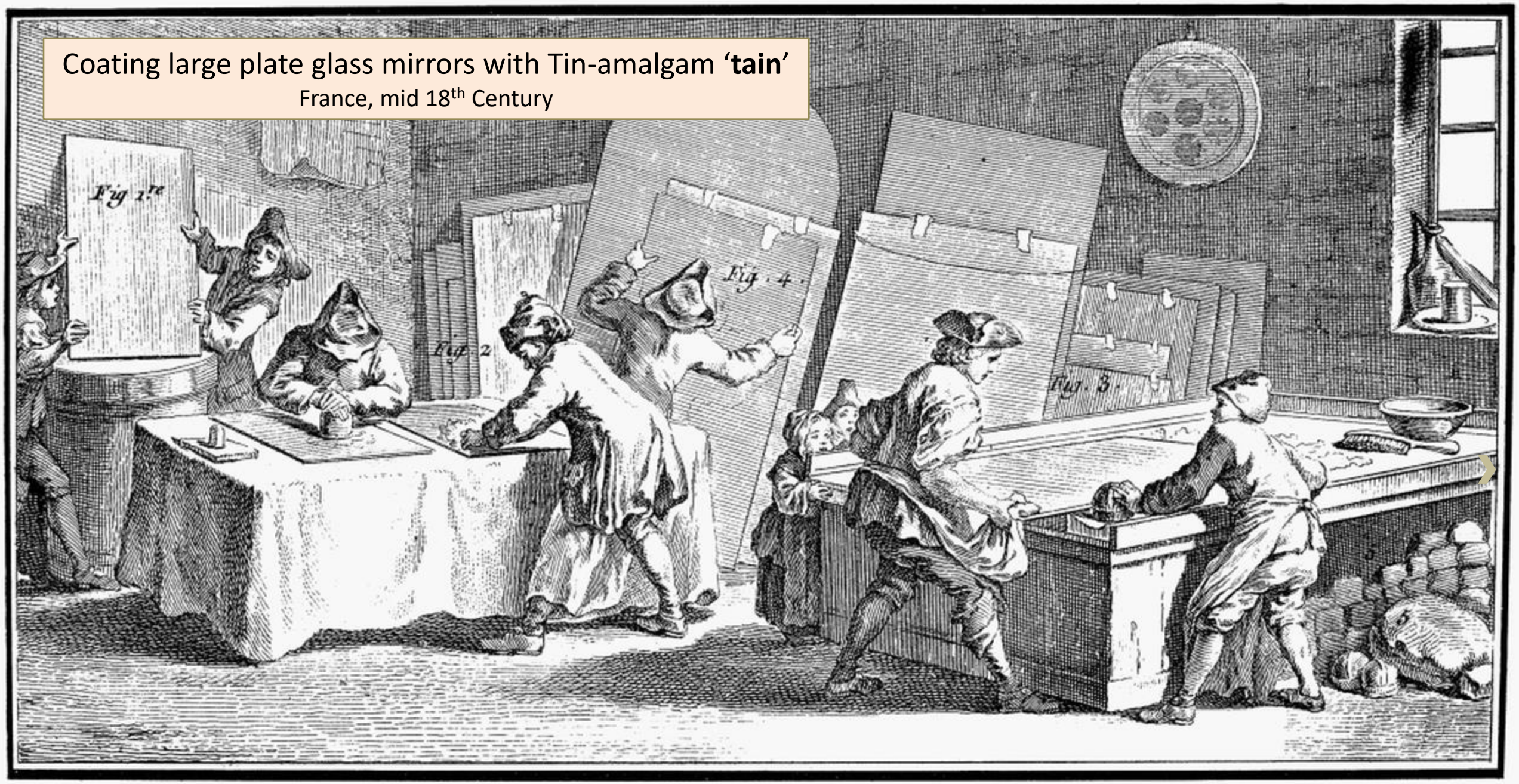


Plate Glass Casting *ca* 1888 (Pennsylvania)

Process nearly unchanged from that used in 1699 at St. Gobain



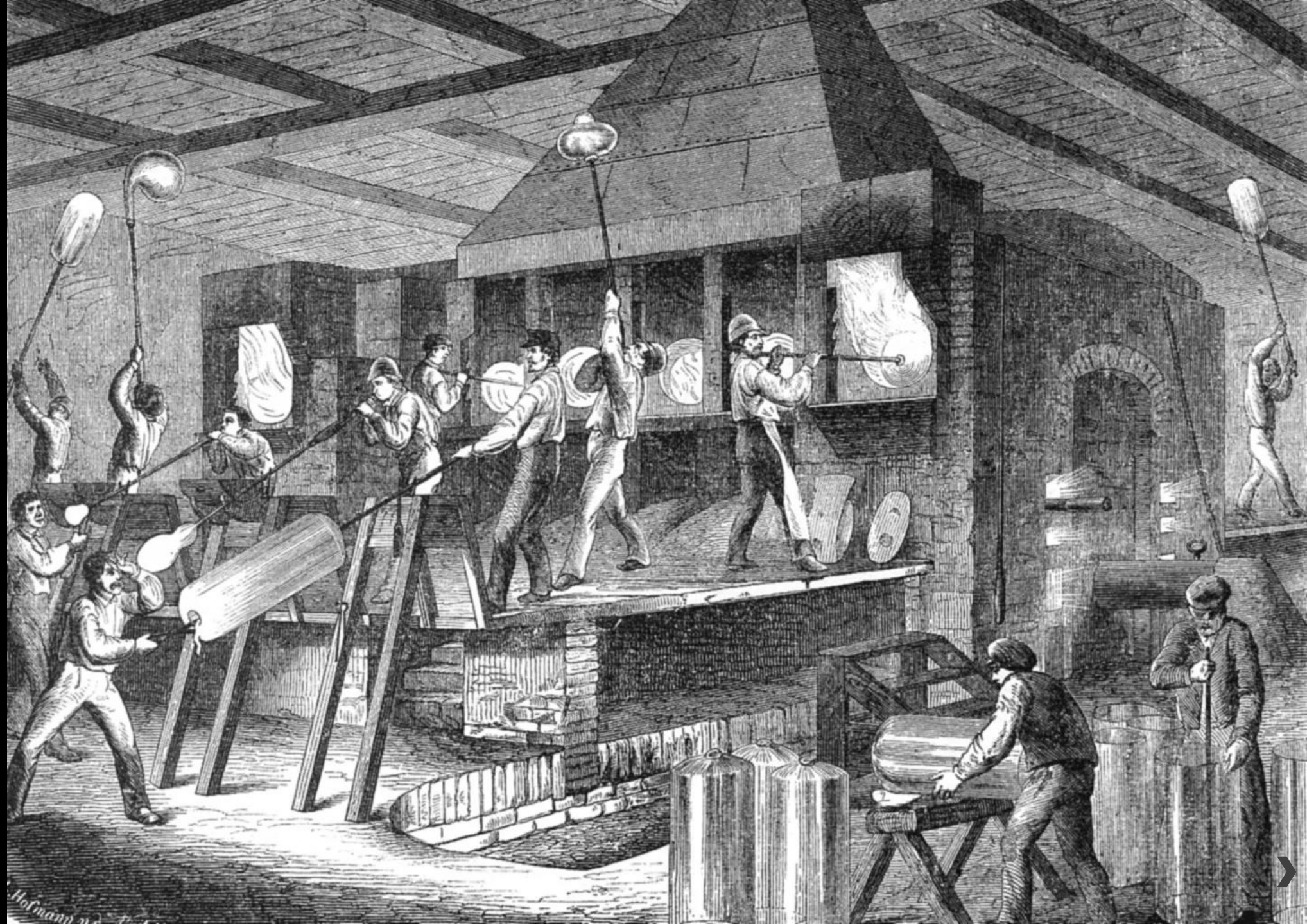
Popular Science Monthly
March 1889 issue


Coating large plate glass mirrors with Tin-amalgam '**tain**'
France, mid 18th Century
Fig 1re
Fig. 2
Fig. 4.
Fig. 3.

German Glassworks 19th Century

Blown glass cylinders to be unrolled for flat glass sheets

(Encyclopedia Britannica 1865)

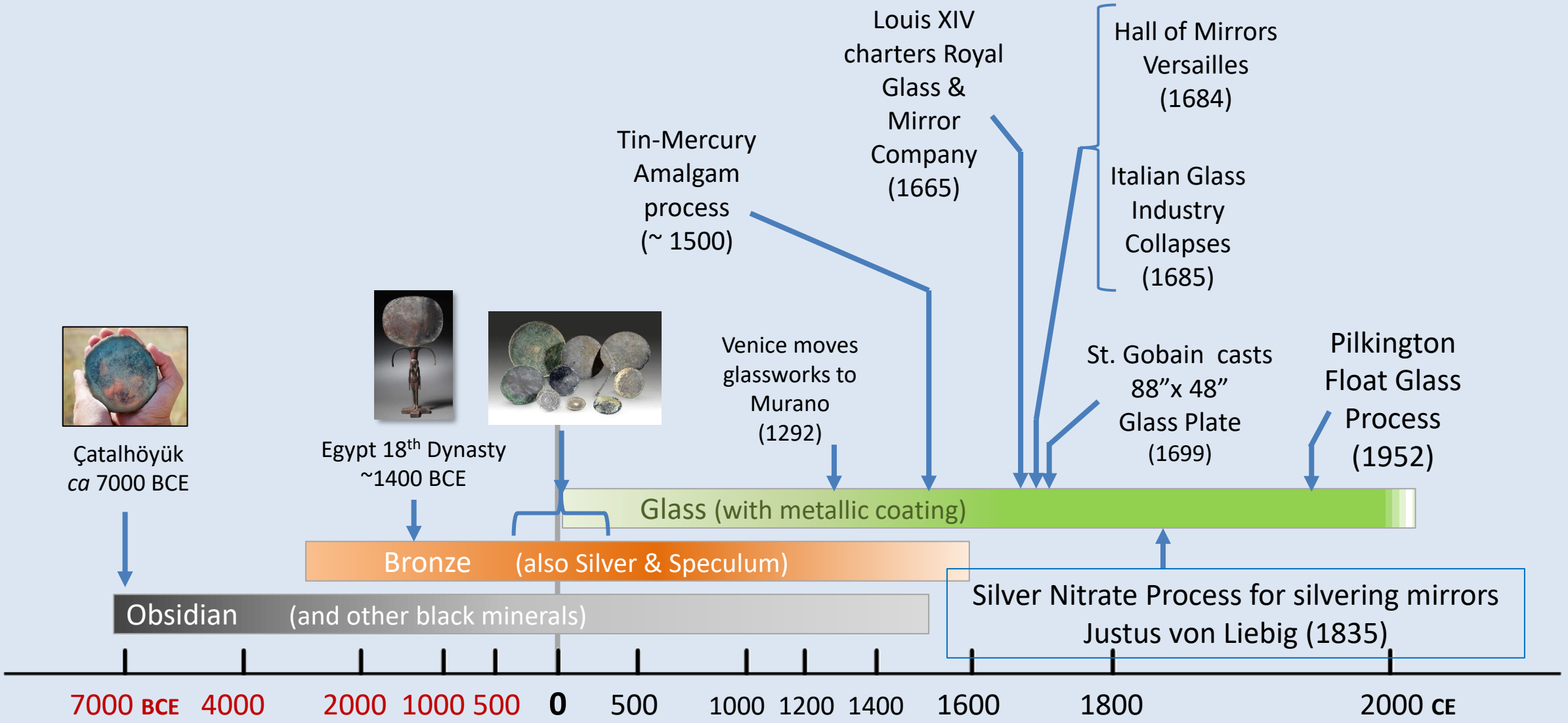


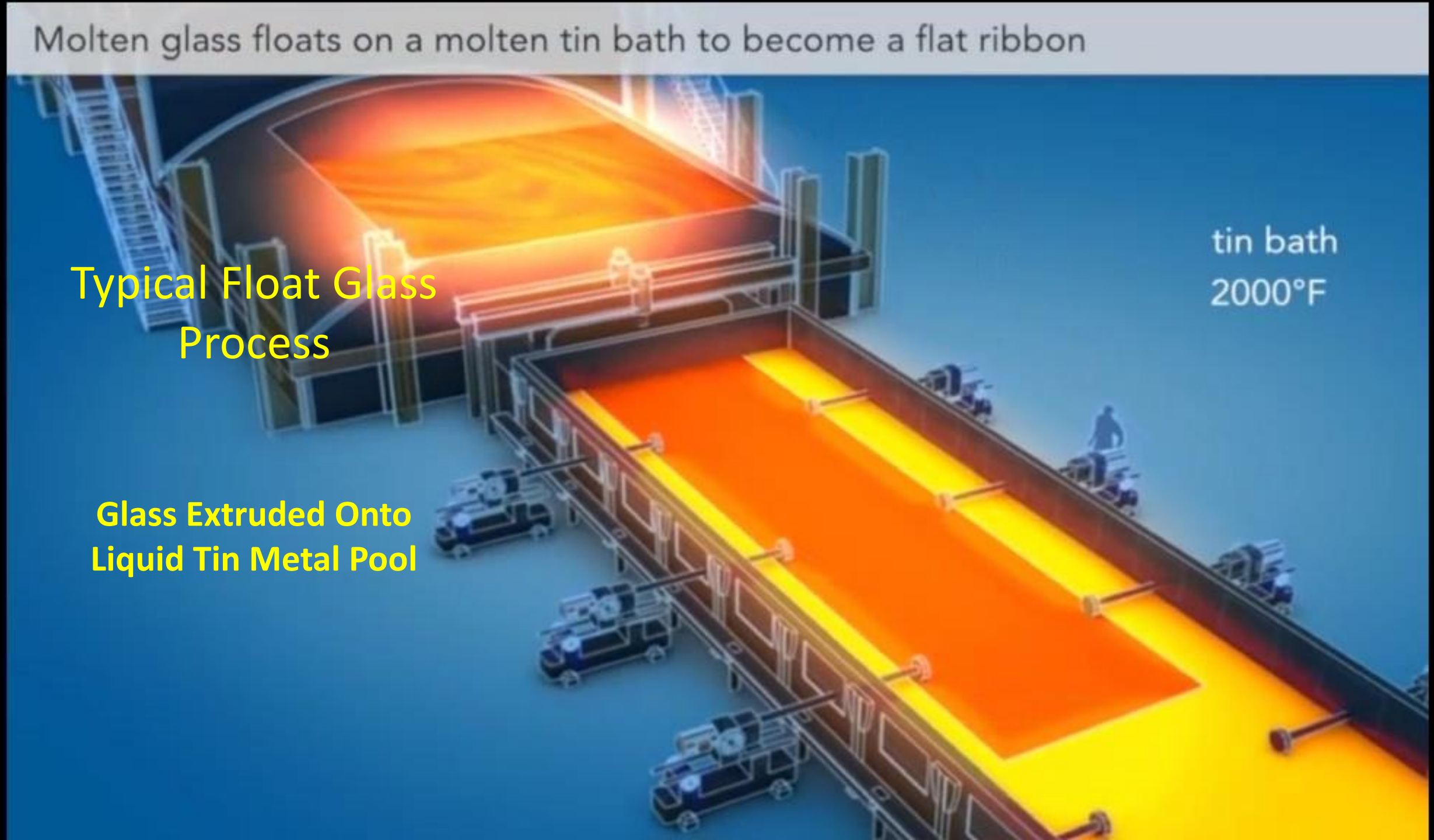
Broadglass Technique for making sheets of flat glass

…. a modern demonstration by an antique glass house in Seattle

Fremont Glass Demo - Antique stain glass windows - Blown glass - YouTube

Timeline for Mirror Technology

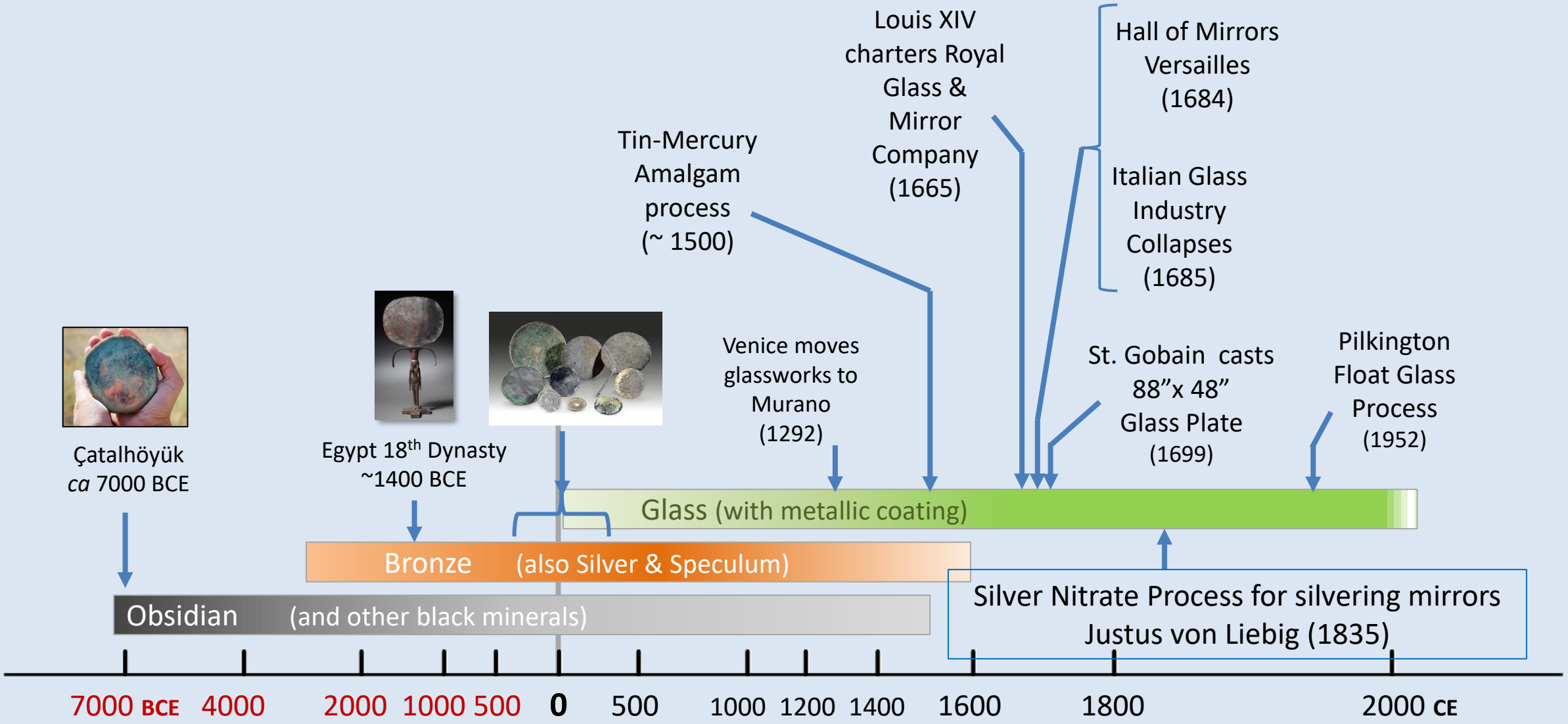




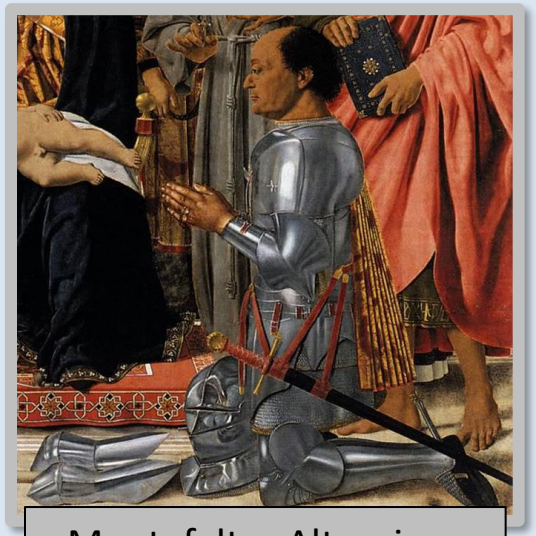
Typical Float Glass Process

Glass Extruded Onto Liquid Tin Metal Pool

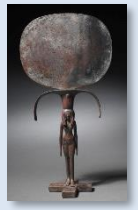
Timeline for Mirror Technology



Timeline for Mirror Technology



Montefeltro Alterpiece
Piero della Francesca
1472



Çatalhöyük
ca 7000 BCE

Egypt 18th Dynasty
~1400 BCE

Tin-Mercury Amalgam process (~ 1500)

Louis XIV charters Royal Glass & Mirror Company (1665)

Hall of Mirrors Versailles (1684)

Ital… Ir… Co…

Venice moves glassworks to Murano (1292)

St. Go… 8…

…Glass Plate (1699)

…Process (1952)

Steel mirrors were the *most common* everyday mirrors up to *ca* 1600

Glass (with metallic coating)

Steel

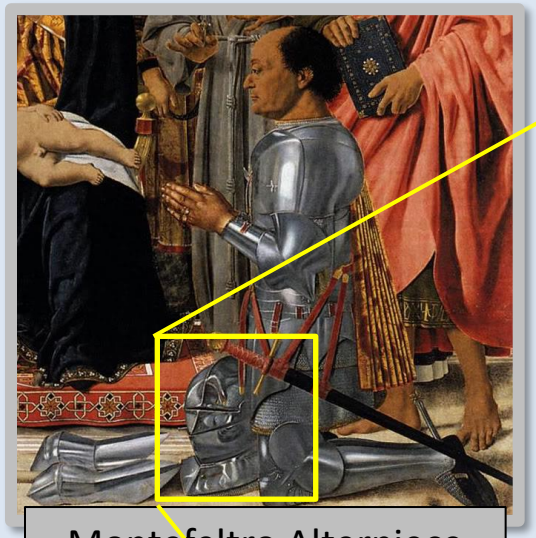
Bronze (also Silver & Speculum)

Obsidian (and other black minerals)

Silver Nitrate Process for silvering mirrors
Justus von Liebig (1835)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Timeline for Mirror Technology



Montefeltro Alterpiece
Piero della Francesca
1472

Çatalhöyük
ca 7000 BCE

Egypt
~1

Obsidian (and oth

Louis XIV
charters Royal

Hall of Mirrors
Versailles
(1684)

Ital
In
Co

St. Go
8

Glass Plate
(1699)

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But they've all rusted away…

Silver Nitrate Process for silvering mirrors
Justus von Liebig (1835)

7000 BCE 4000 2000 1000 500 0 500 1000 1200 1400 1600 1800 2000 CE

Modern
Stainless Steel
Camping Mirror

Amazon.com

Hall of Mirrors
Versailles
(1684)

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But they've all rusted away…

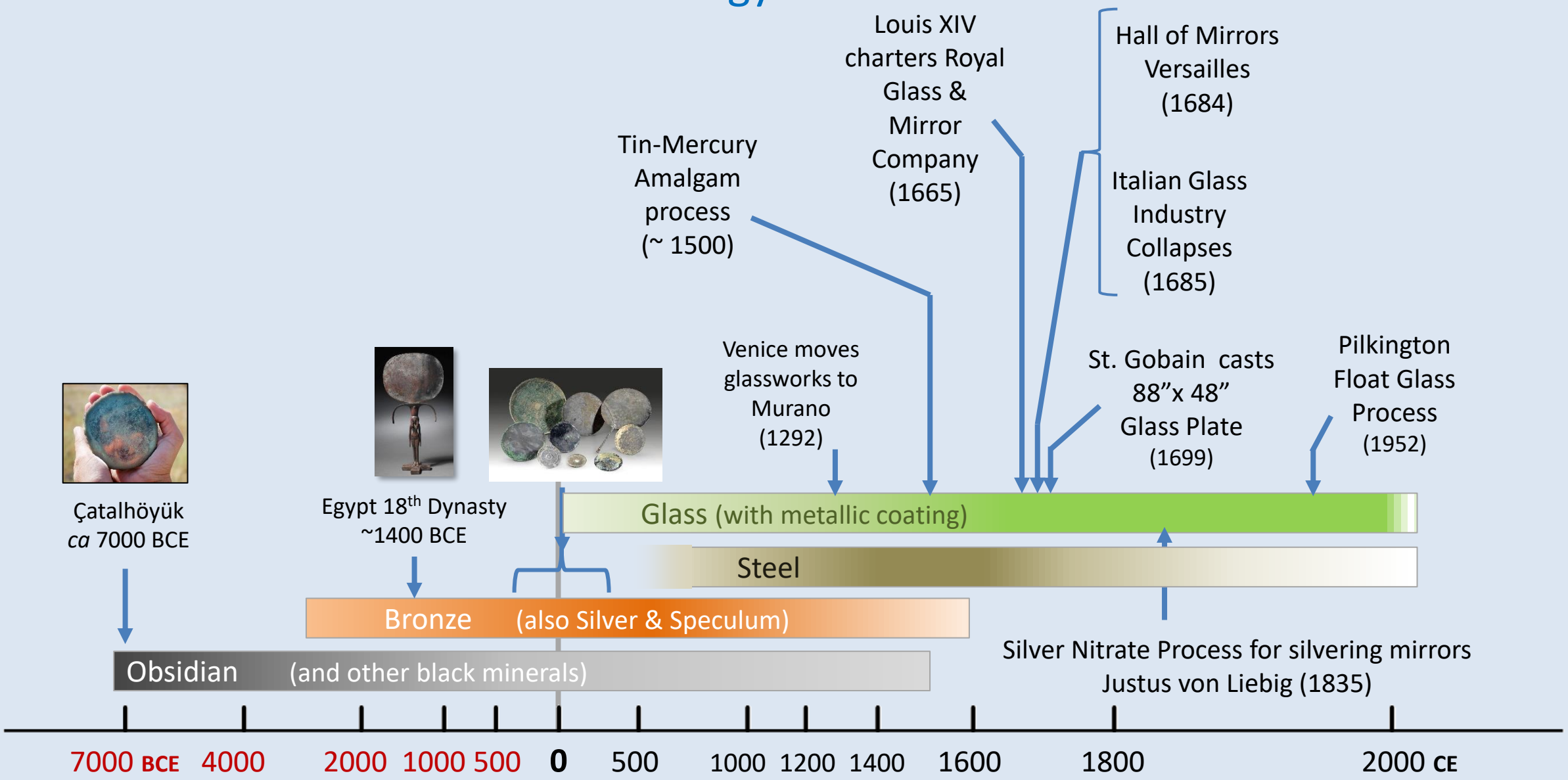
Glass Plate
(1699)

er Nitrate Process for silvering mirrors
Justus von Liebig (1835)

1800

2000 CE

Timeline for Mirror Technology



Back to Antiquity….

Excerpts from
colorized version of the
1914 Epic Film

Cabiria

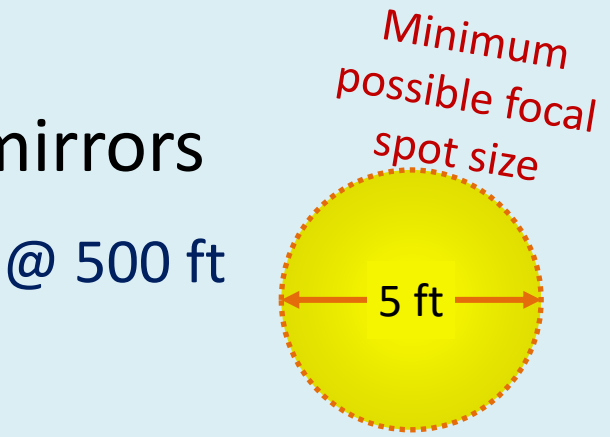
Directed by
Giovanni Pastrone

Episode 4:
The Roman Siege of Syracuse
212 BCE
2nd Punic War

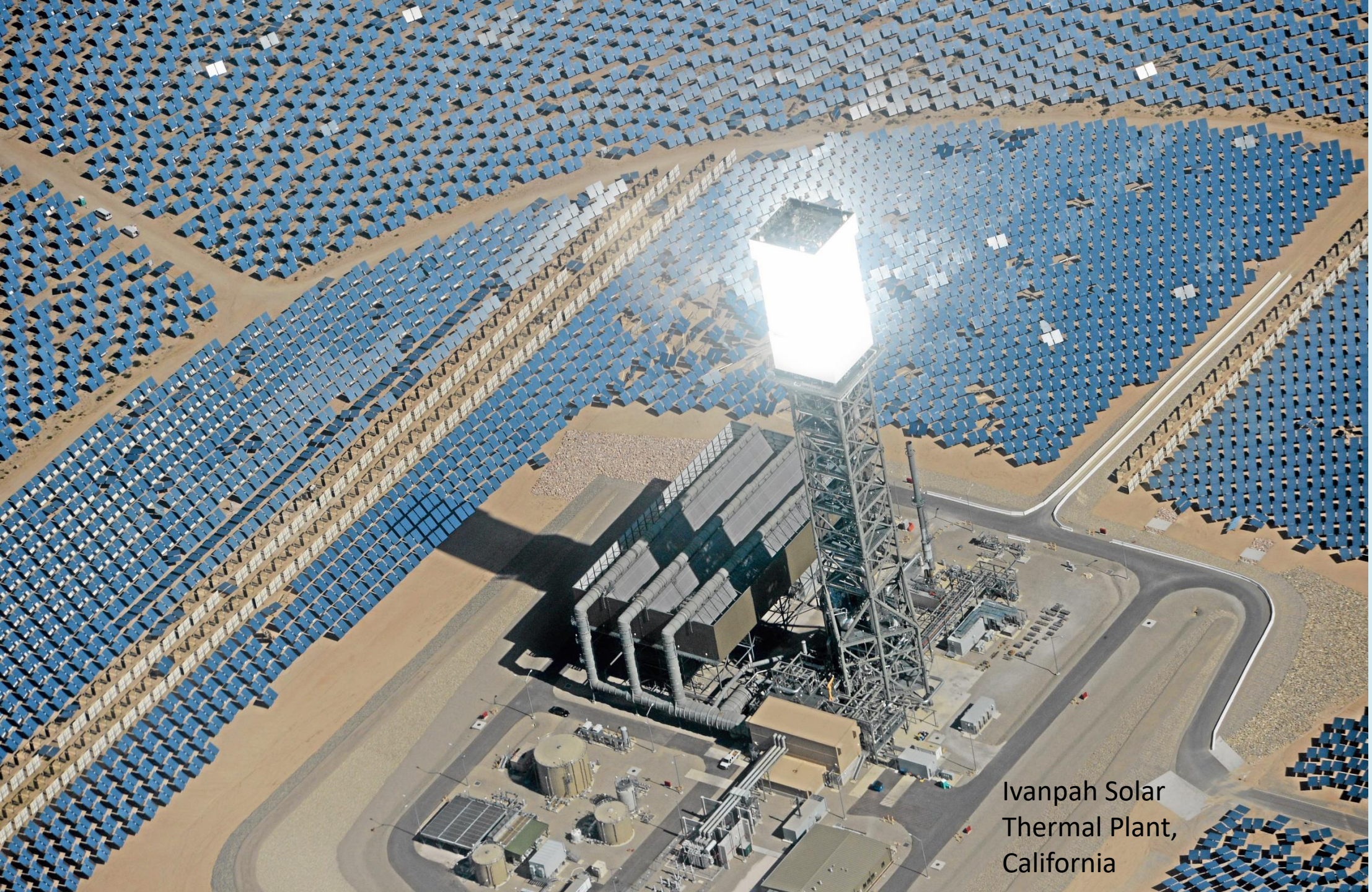
Scene from Cabiria, Episode 4 (1914)

Did It Happen in 212 BCE?

- Burning mirrors *were* known to the Greeks (e.g. Diocles *ca* 200 BCE)
- Bronze mirrors of suitable size could be made
- Archimedes had the smarts
- At a distance of a "bowshot", it would take a *lot* of mirrors
  - But it is certainly possible
    - Buffon (1750) and Sakkas (1973) experiments, e.g.

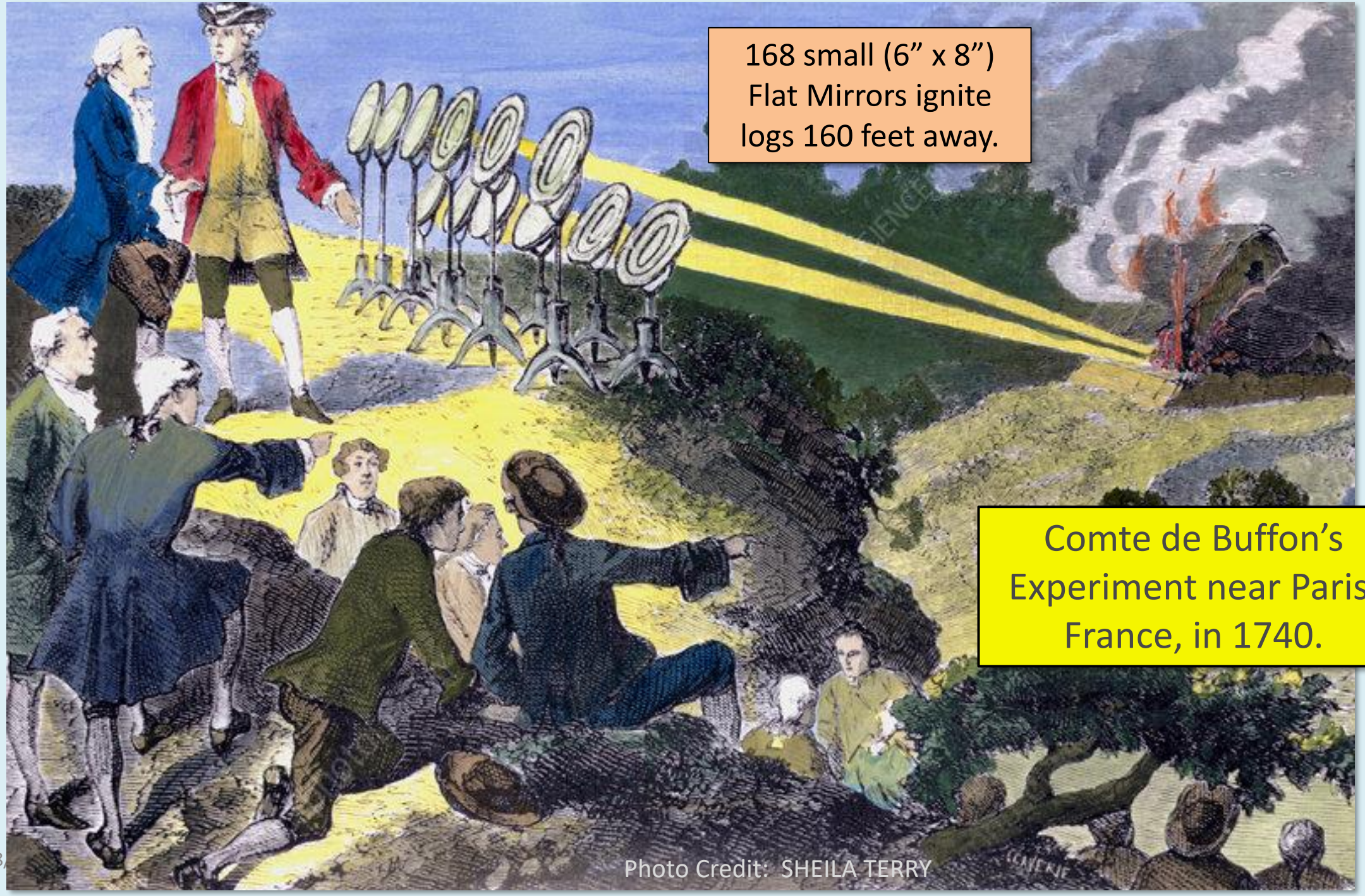


- Historical Textual Evidence is quite weak
  - Contemporary historians do not mention it (Polybius in particular)
  - Most detailed accounts come from John Tzetzes (Byzantine *ca* 1150)
- Practical?
  - Large military effort, Simple countermeasures.



Ivanpah Solar Thermal Plant, California

Solar Power Plant Target Temperatures easily reach 1000F

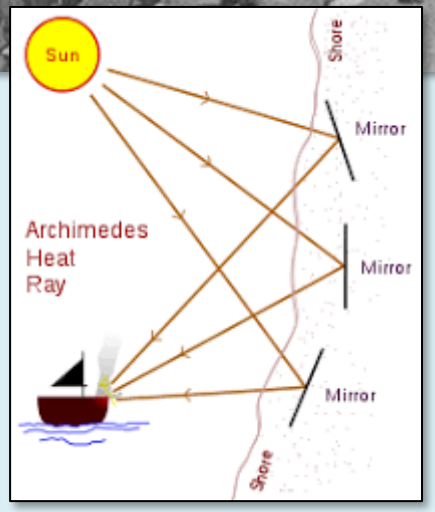

168 small (6” x 8”) Flat Mirrors ignite logs 160 feet away.
Comte de Buffon’s Experiment near Paris, France, in 1740.
Photo Credit: SHEILA TERRY

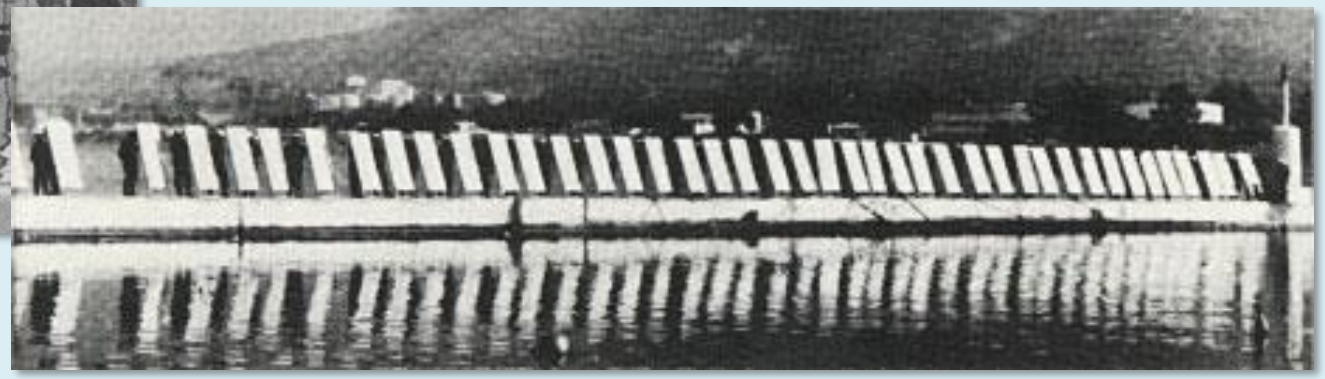
The Sakkas Demonstration (1973)

Dr. Ioannis Sakkas lines up **~70** rectangular mirrors manned by Greek sailors, aimed at target mockup of Roman boat 160 feet away. Mirrors copper coated.

The plywood boat, coated with **black tar**, was reported to burst into flames in seconds once aiming was perfected.

Skaramagas Naval Base,
Athens
Autumn 1973

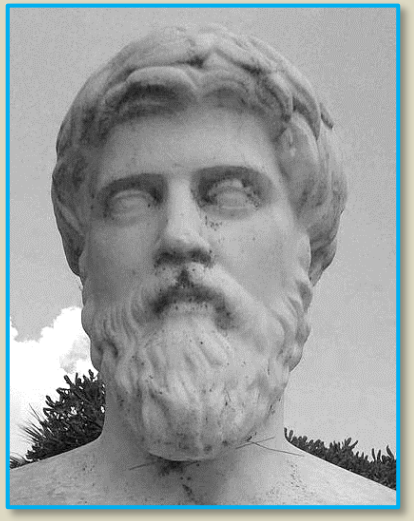




Temple of Vesta, Rome

Jean Raoux (1727)

Vestal Virgins tasked with keeping the Eternal Flame alive..

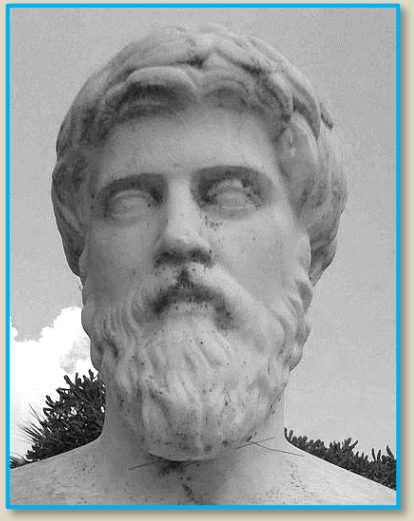


Plutarch (30-105 CE)
Parallel Lives, Numa

"… but new fire is to be gained by drawing a pure and unpolluted flame from the sunbeams. They kindle it generally with concave vessels of brass…"

Temple of Vesta, Rome

Similar to Ancient Greek
Skaphia σκαφια



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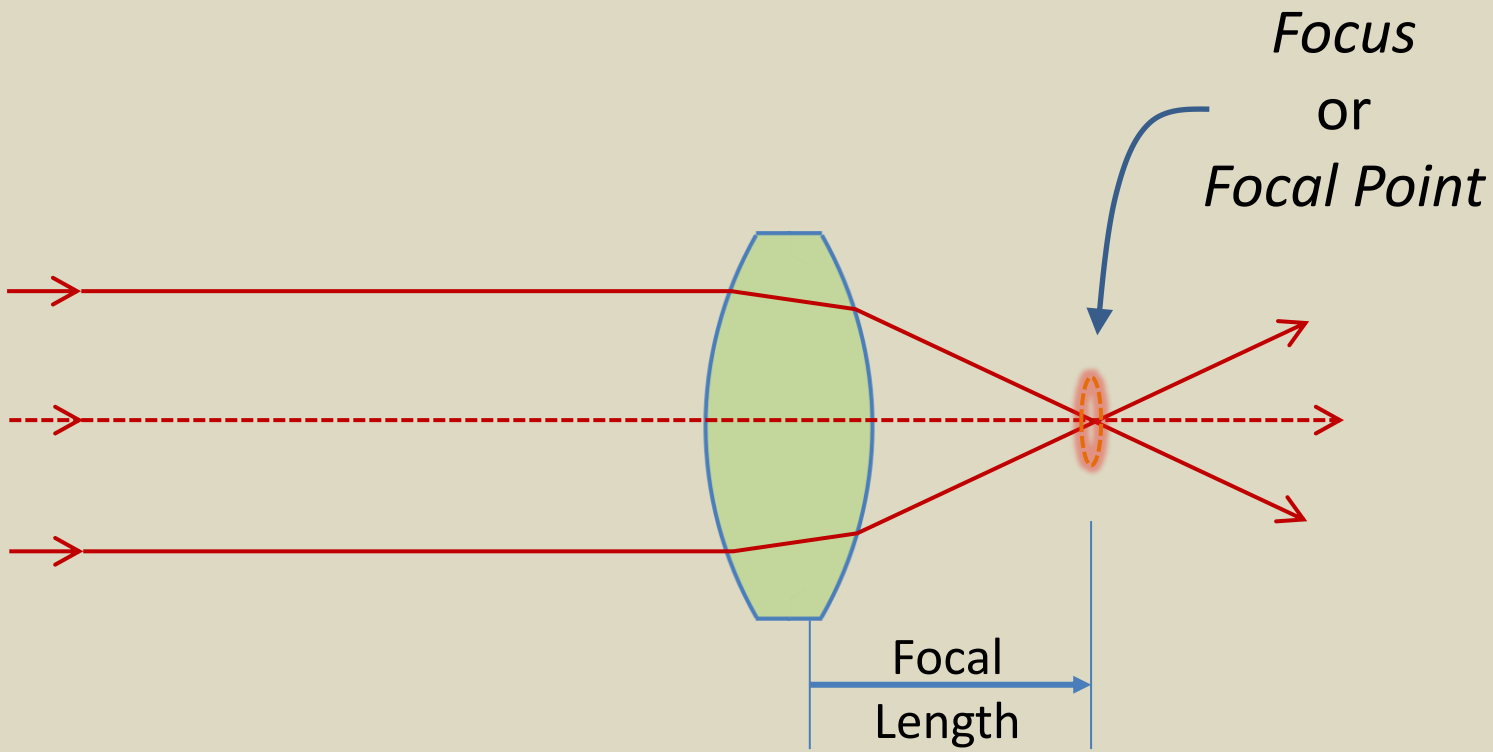
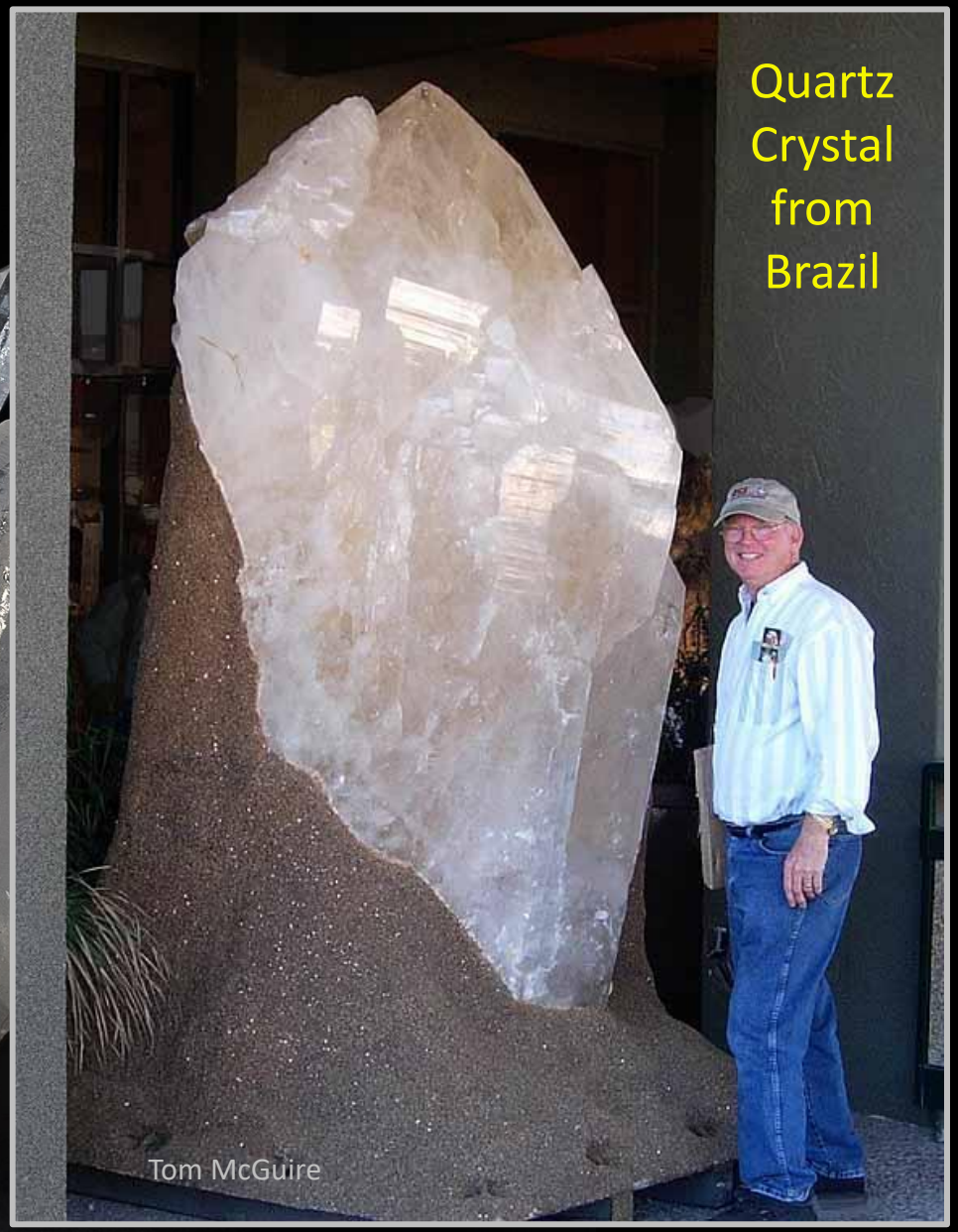
Refractive Optics: Lenses



Crystal Quartz from Tibet

Silicon Dioxide
SiO_2



Nimrud "Lens"

ca 750-710 BCE

Found 1850 at the Assyrian Palace of Nimrud

~40 mm diameter
~6 mm thick

Roughly Ground and Polished
Plano-Convex

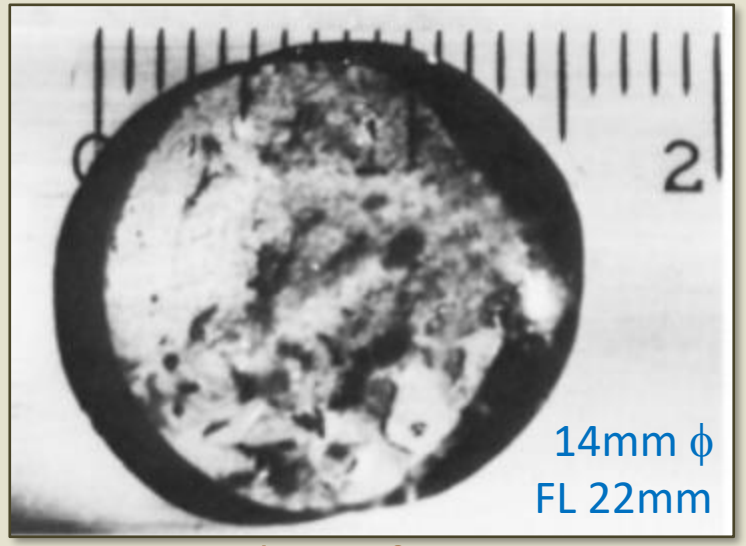
~ 12 cm Focal Length

"Decorative Inlay"

British Museum

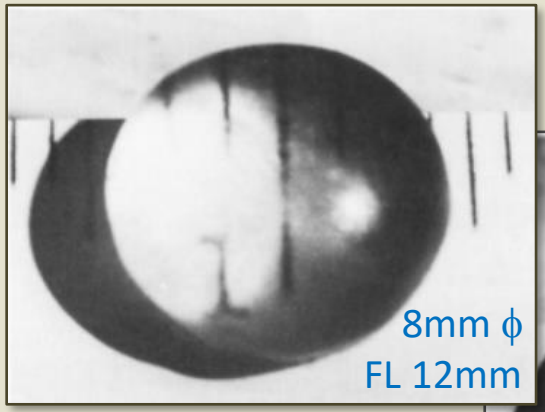
Other Rock Crystal Lens-like Artifacts

- Many in museum drawers
- Examples: Herakleion Museum (Crete)

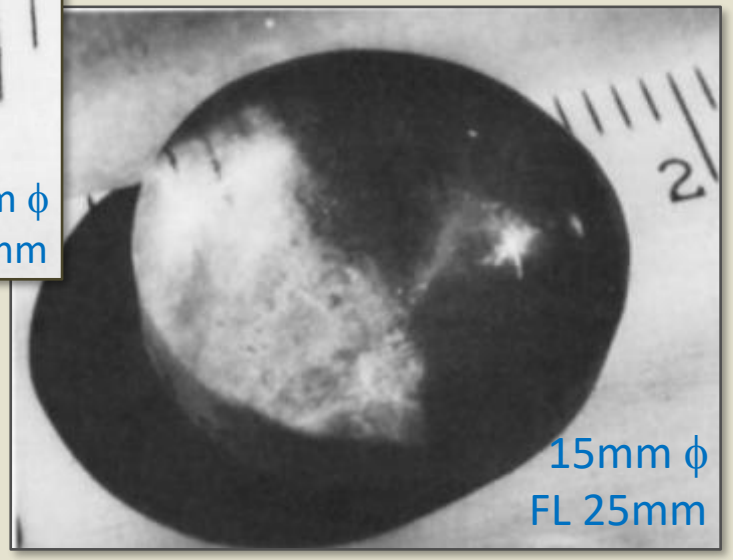


Palace of Knossos,
ca 1400 BCE

- Schliemann Excavation
  at Troy (*ca* 1870)
  - 42-46 lens-like Quartz artifacts
    ca 2200 BCE



Idaean Cave, Crete
Archaic Greek
600 BCE**?**



Photos from Sines & Sakellarakis,
"Lenses in Antiquity" (1987)

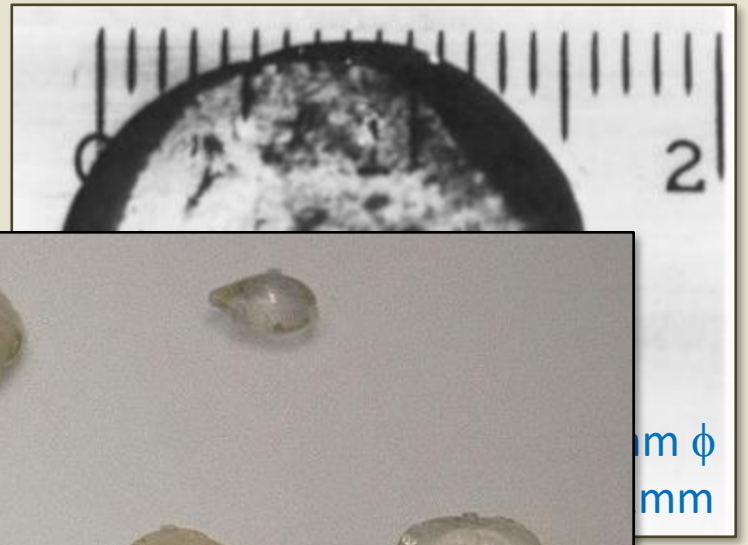
Other Rock Crystal Lens-like Artifacts

-
-
-

Archeological Museum of Heraklion
Crete 1600-1450 BCE

Probably Ornamental

600 BCE?



m ϕ
mm

15mm ϕ
FL 25mm

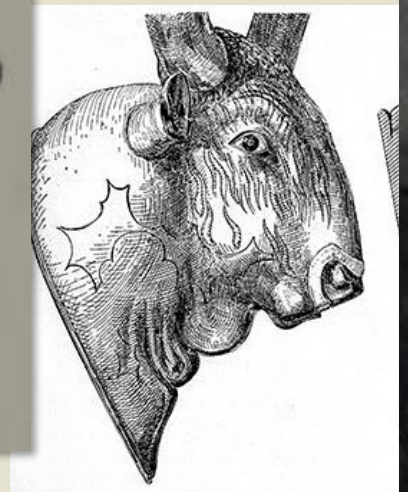
Photos from Sines & Sakellarakis, "Lenses in Antiquity" (1987)

Is it a lens, or just art?

Bull's Head Rhyton (libation vessel) from Minoan Palace at Knossos c. 1550 BCE

Archaeological Museum of Heraklion, Crete

Carved from solid Steatite with Crystal Quartz Eye



Bull’s Head Rhyton

ca 1550 BCE

What might such lenses have been used for, besides decoration?

Babylon 2000 BCE

*Sacred glass,
sun-glass used to
light the sacred fire

The King then rises, takes the sacred glass*,
And holds it in the sun before the mass
Of waiting fuel on the altar piled.
The centring rays--the fuel glowing gild
With a round spot of fire and quickly spring
Above the altar curling, while they sing!

from the Royal Library of Ashurbanipal
at Nineveh (near Mosul) *ca* 600 BCE

The Epic of Ishtar and Izdubar (Gilgamesh):

Alcove I, Column IV, Coronation of Izdubar

Translation by Leonidas Hamilton (1884)

A Scene from

Νεφέλαι
The Clouds
Aristophanes
423 BCE

Key Characters:

Socrates --
A philosopher who runs The Thinkery

Strepsiades –
An elderly farmer – a ‘country bumpkin’

Performance at Bergen Community College, Paramus NJ March 2, 2016

Aristophanes
"The Clouds"
423 BCE

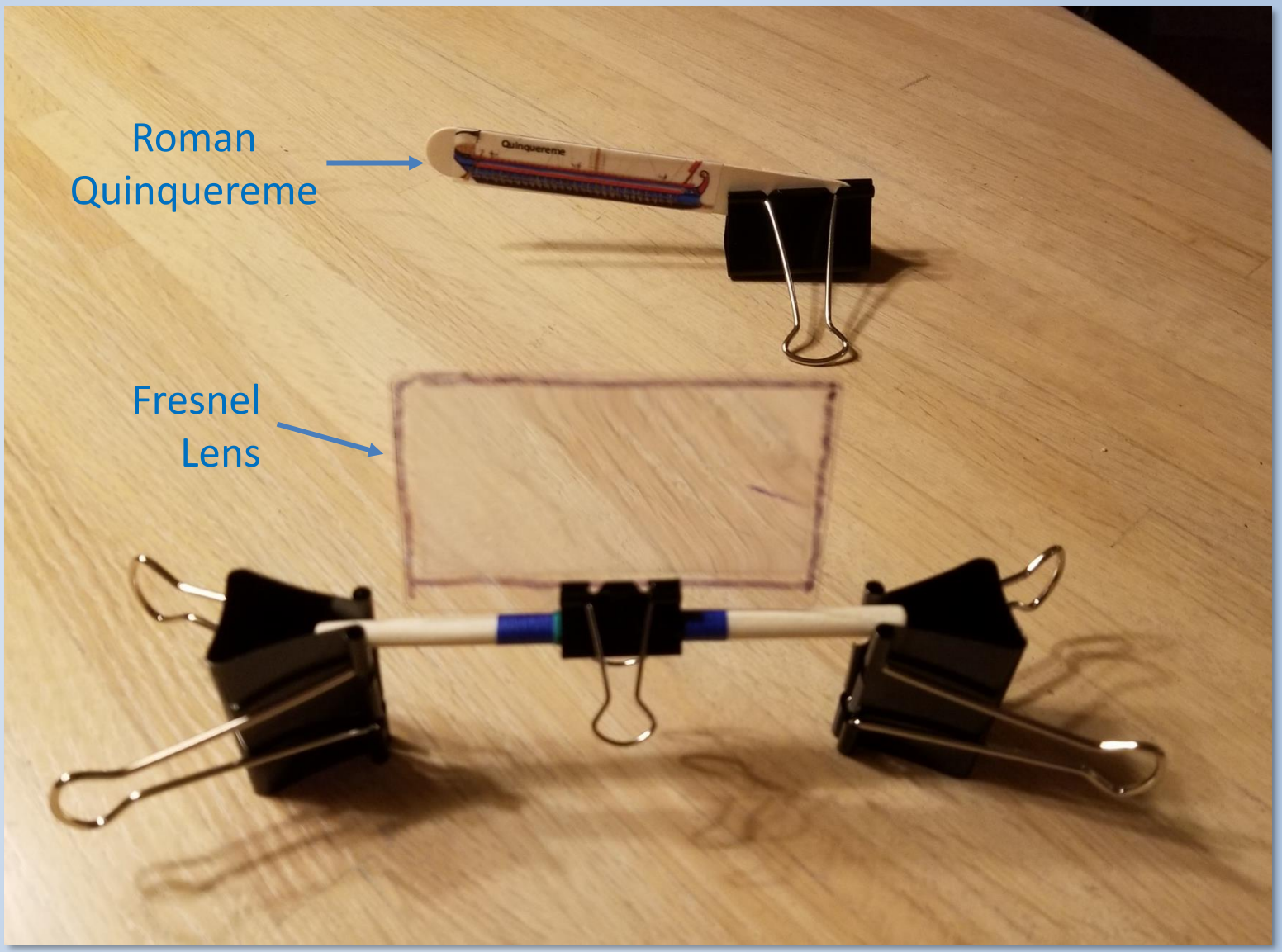
STREPSIADES: Have you ever seen a **beautiful, transparent stone** at the druggists', with which you may **kindle fire**?

SOCRATES: You mean a **Crystal Lens**?

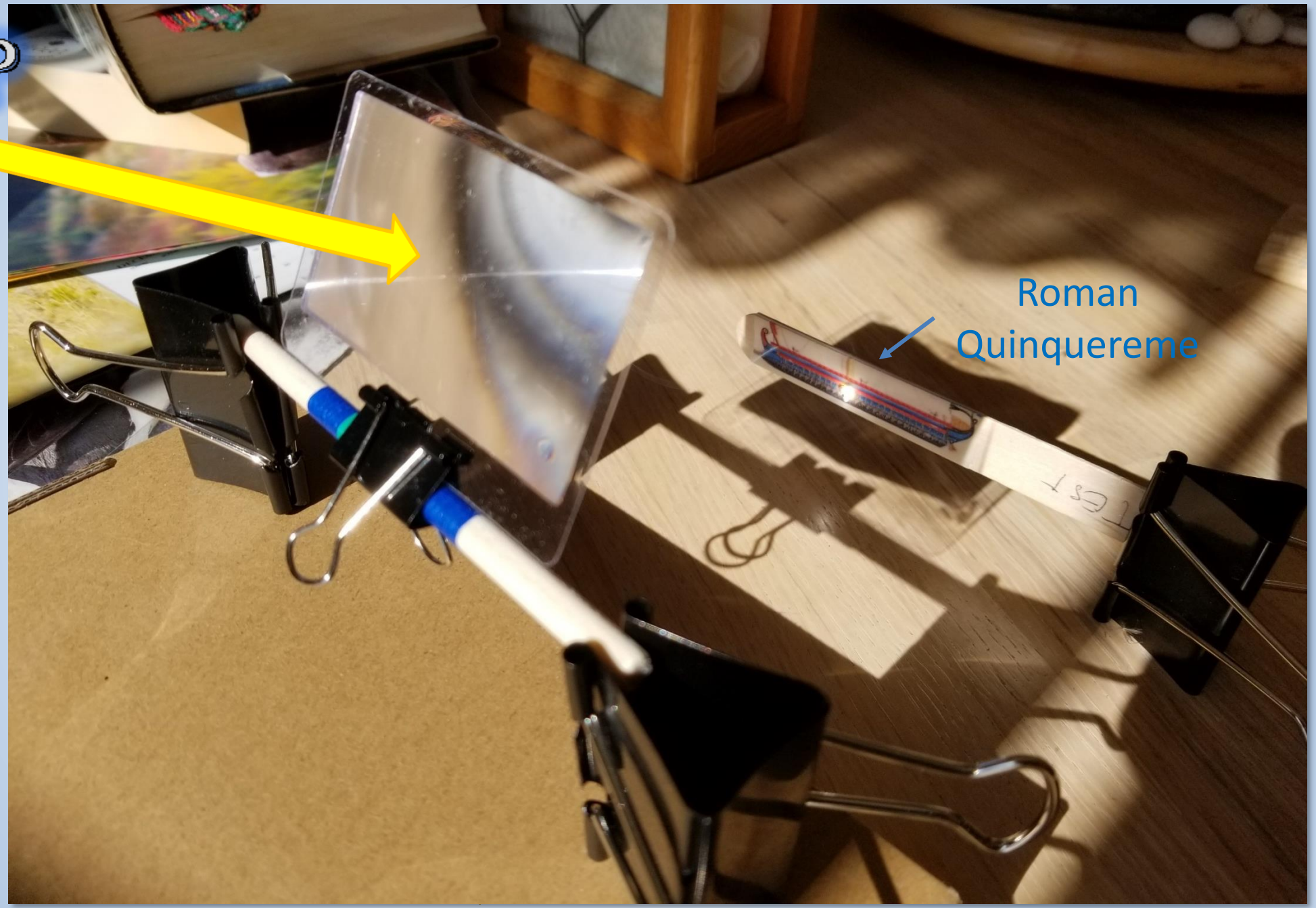
OLLI-OP

Your Kit contains everything you need to test a Burning Glass:

- *Fresnel Lens*
- *Target Ship*
- *Holder Clips*

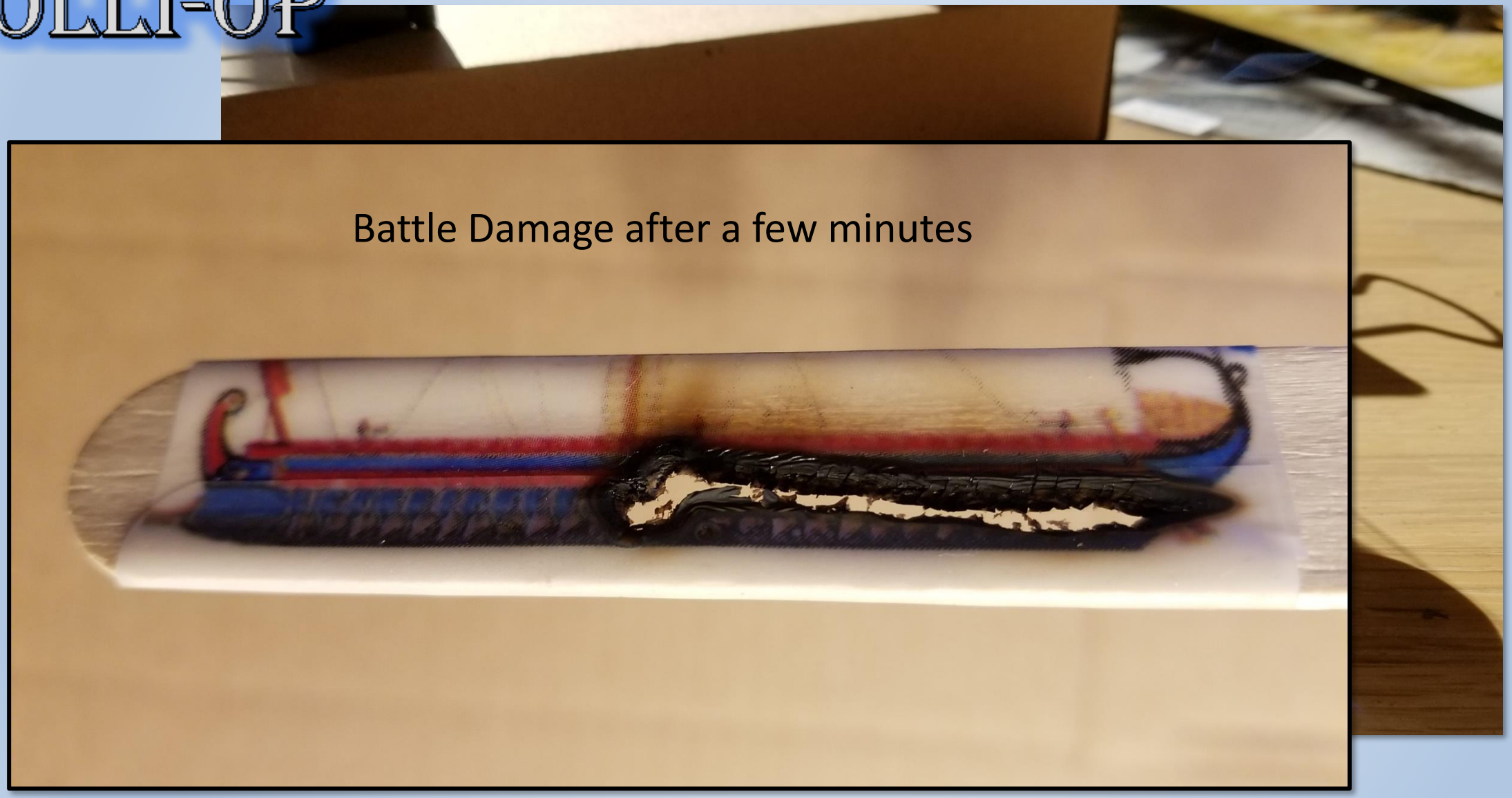


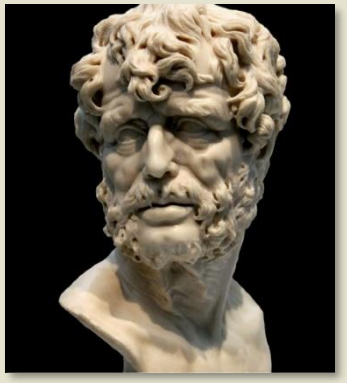
OLLI-OP



Ship
Smoking
(Video)

OLLI-OP





Seneca (the Younger)
(4 BCE- 65 CE)

"Writing, however tiny and difficult, is seen **larger and clearer** through a **glass sphere full of water**…"

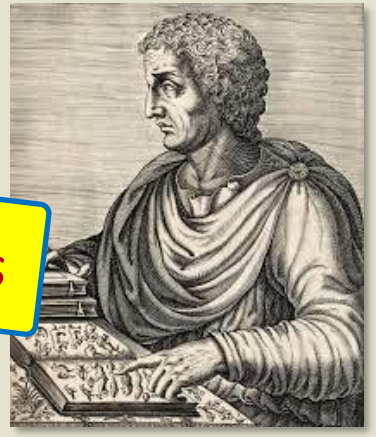
Naturales Quaestiones Book 1, 6.5 (63 CE)
Trans. Harry Hine (2010)

First textual mention of magnification by a lens

"I find it stated by medical men that the very best **cautery** for the human body is a **ball of crystal** (quartz) acted upon by the **rays of the sun**."

Naturalis Historiæ 37.10 (~79 CE)

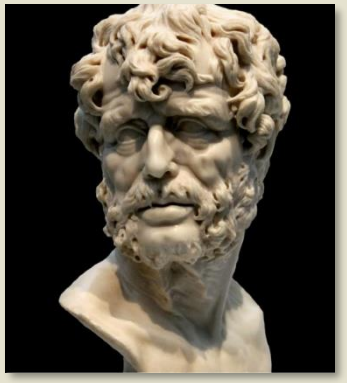
Old News



"…we find that **globular glass vessels**, filled with water, when brought in contact with the **rays of the sun**, become heated to such a degree as to cause articles of clothing to **ignite**."

Naturalis Historiæ 36.67
(~79 CE)

Pliny the Elder
(23-79 CE)



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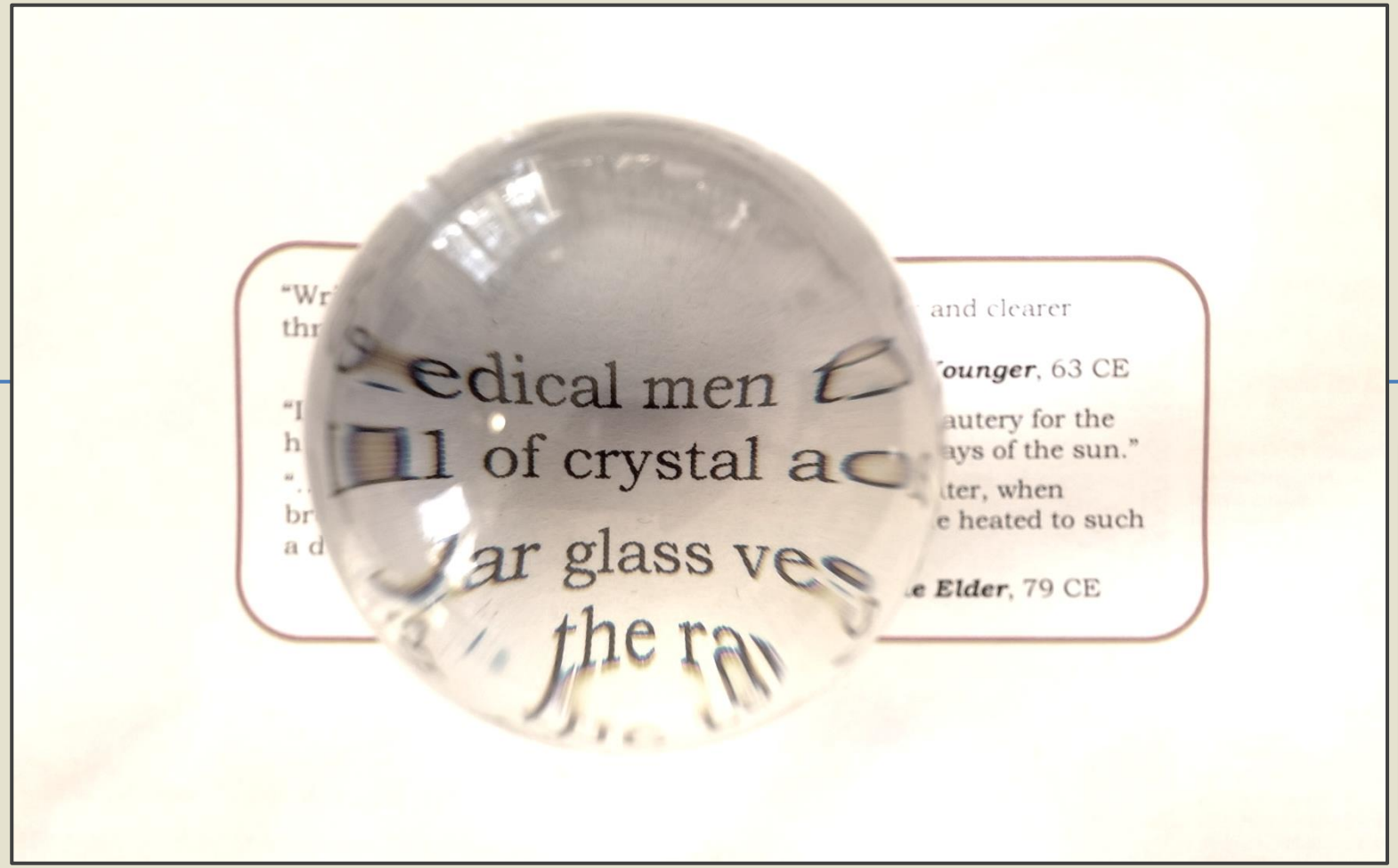

Pliny the Elder
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Early Timeline of Optical Science

Euclid
~ 330-280 BCE
Alexandria?

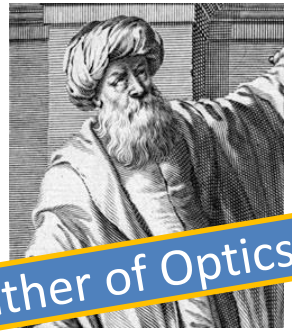
Optics
c 300 BCE

Ptolemy
100-170 CE
Alexandria

Optica
c 150 CE

Al-Kindi
c. 801-873 CE
Baghdad

De Aspectibus
c 850 CE

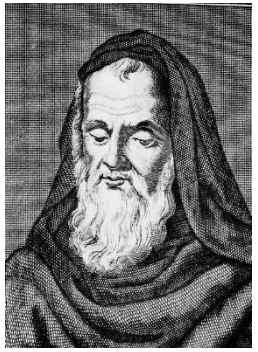


"Father of Optics"

Ibn al-Haytham
(**Alhazen**)
c. 965-1040 CE
Cairo

Book of Optics
c 1020 CE

Latin Translation ~1200

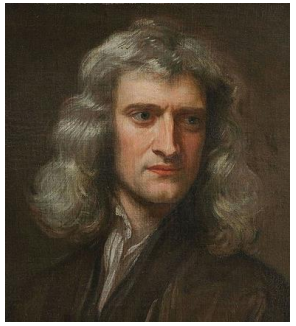


Roger Bacon
c. 1220-1292 CE
Oxford

Science of Perspective
1267 CE

Johannes Kepler
1571-1630 CE
Prague

Astronomiae Pars Optica
1604 CE



Isaac Newton
1643-1727 CE
Cambridge

Optiks
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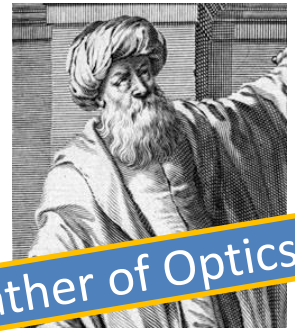

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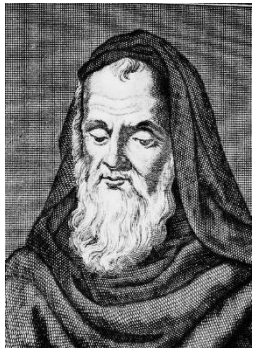

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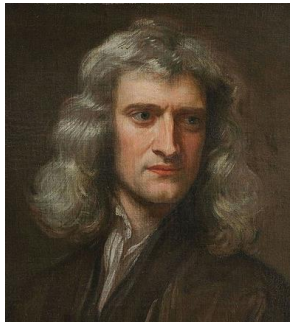

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1643-1727 CE
Cambridge

Optiks
1704 CE

Tried to understand Vision via Geometry

Believed in *Extramission*

- Rejected *Extramission*
- Used Experimental Method
- Attempted Eye Model

Raised Awareness of Optics

- Detailed theory of mirrors & lenses
- Correct Eye Model
- Refracting Telescope

- Consolidation
- Theory of Color
- Reflecting Telescope

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~ 330-280 BCE
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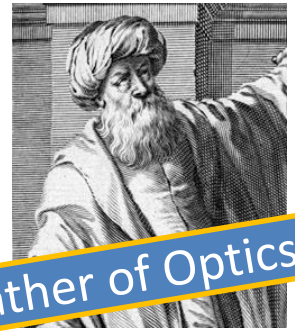

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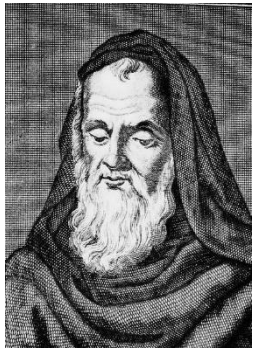

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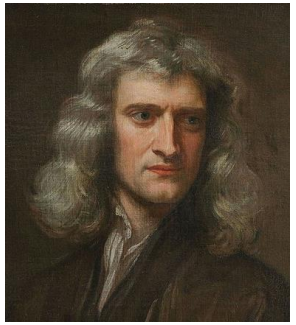

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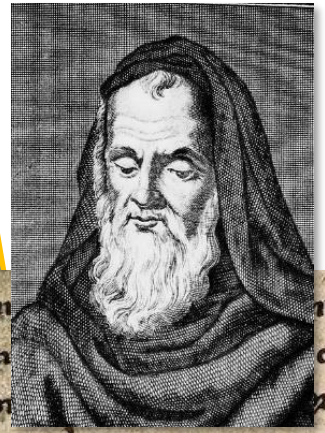
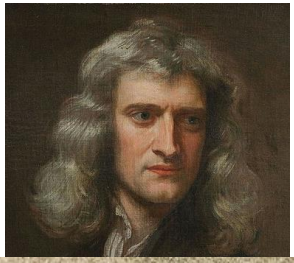
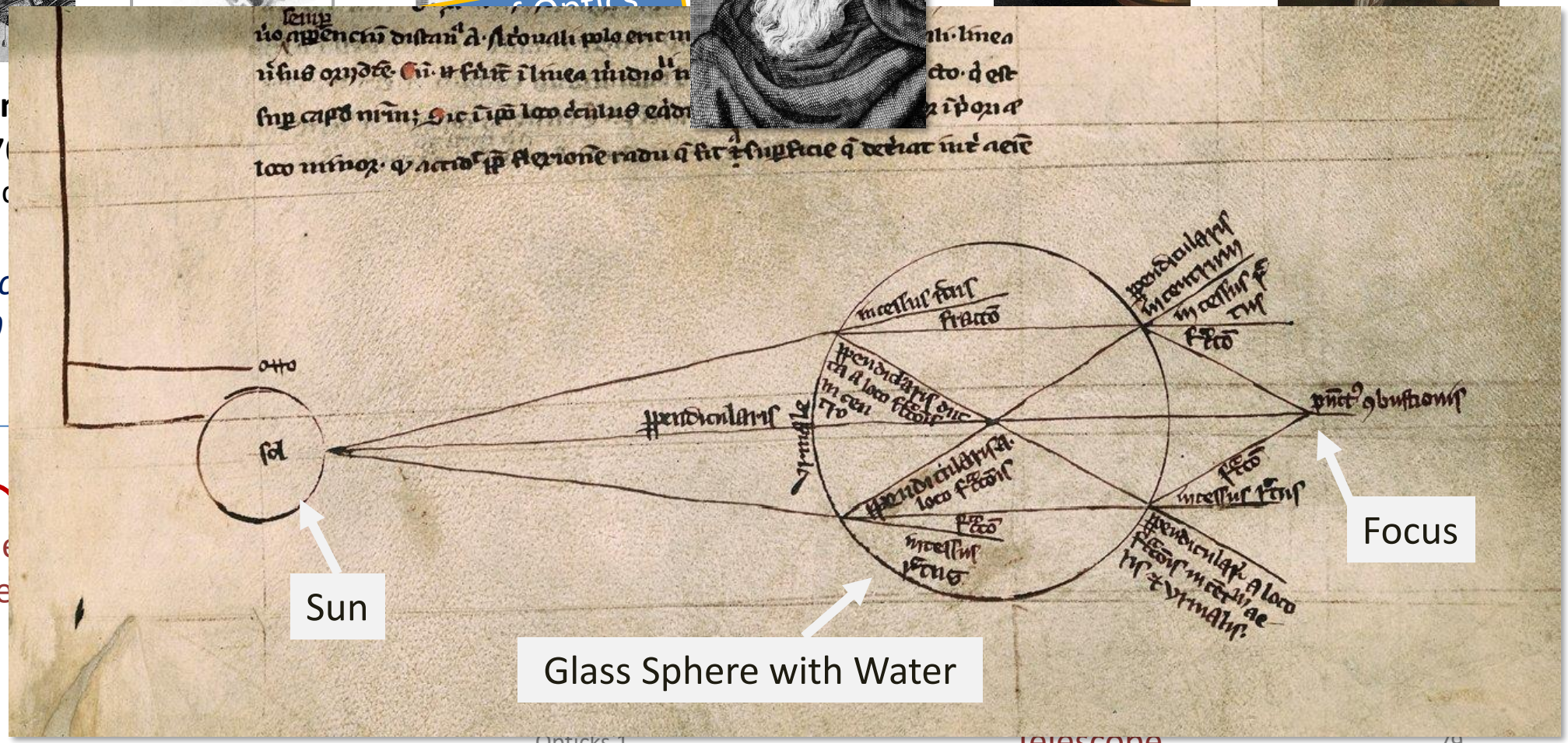




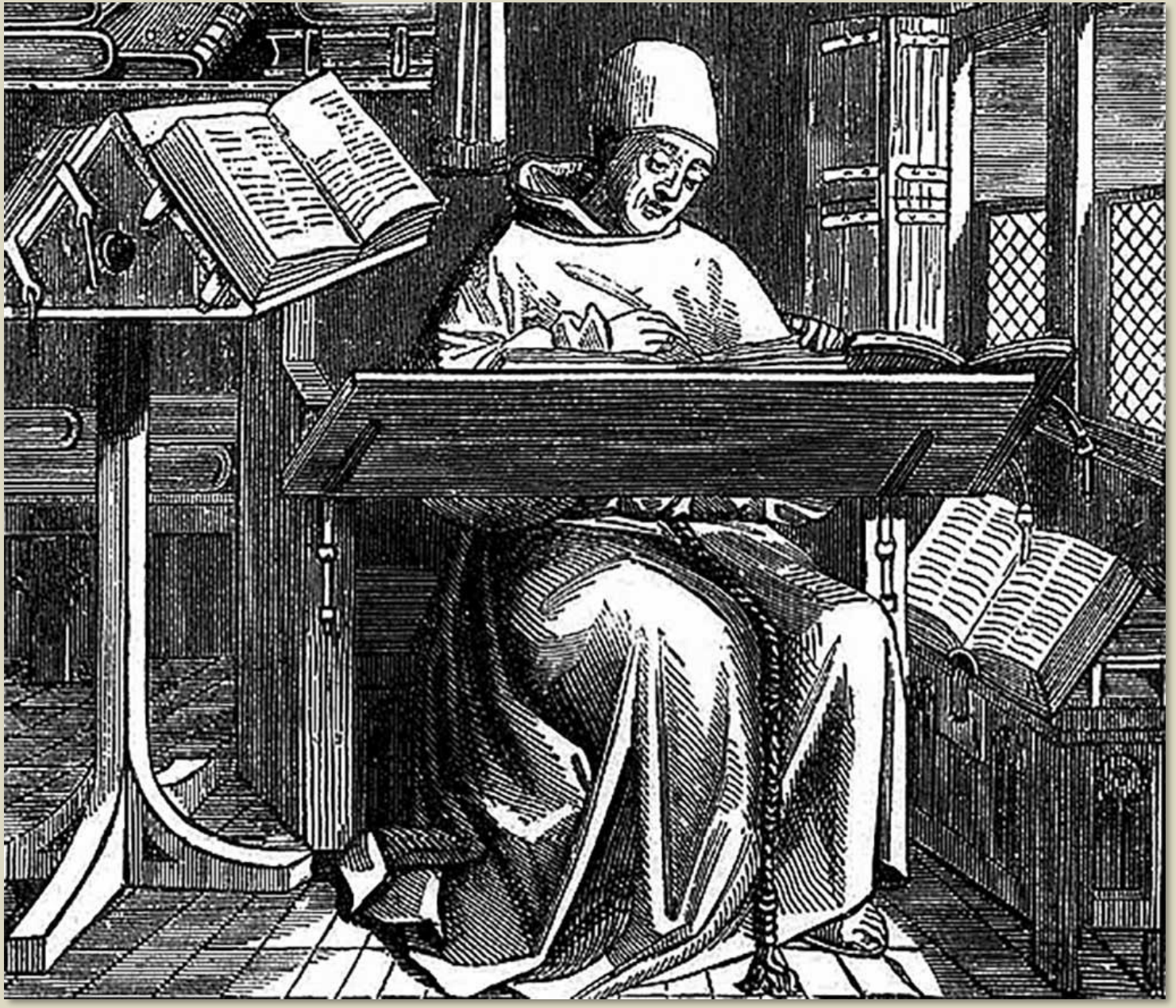
Tried to unde
via Ge

Believed in



Alhazen's *Book of Optics* spreads around Europe following its Latin translation ~ 1200 CE

Did this help trigger the rapid introduction of magnifiers and vision aids over the next two centuries?



Reading Stones *'Lapides ad legendum'*

- Thick plano-convex lenses of Quartz or Beryl
- Placed directly on manuscript for magnification

Beryl

Beryllium Aluminum Silicate

$Be_3Al_2(SiO_3)_6$

Naturally occurring crystals, optically similar to Quartz

Used in Medieval times for lenses

German word for eyeglasses is Brille, from Berillus = 'Beryl'

Quartz lens, possibly a Reading Stone

Provenance unknown

(Lot-Art.com)

The Visby "Lenses"

Gotland

Viking Graves from

11th -12th Century CE

Crystal Quartz

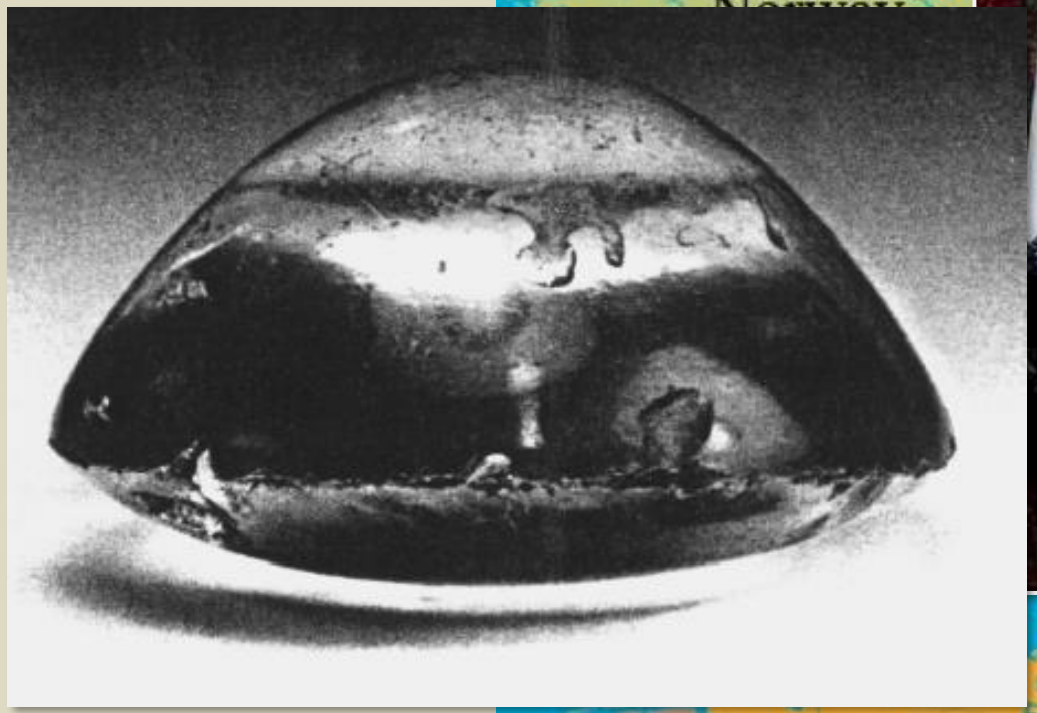
The Visby "Lenses"

Gotland

Viking Graves from

11th -12th Century CE

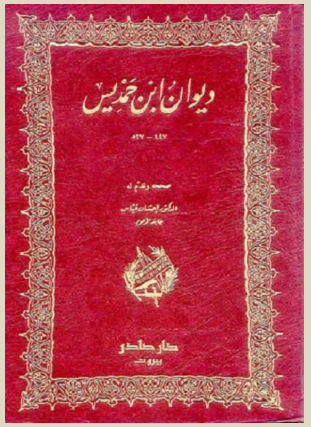
Crystal Quartz



Lenses or Decoration?

A 12th Century Poem of Ibn al-Hamdis

وجدول جامد في الكف تحمله ... يغوص فيه على درّ النهى النظر
يكسو السطور ضياء عند ظلمتها ... كأنه ينبوع نور منه ينفجر
يشف للعين عن خط الكتاب كما ... شف الهواء، ولكن جسمه حجر
يندي الخدود بجرح نالها عرق ... فيه وقرّ عليها جامدا نهر
كحّلت عيني إذ كلّت بجوهره ... أما يُحدّ بكحل الجوهر البصر؟
كأنه ذهن ذي حذق يفك به ... من المعمّى عويصا فكّه عسر
نعم المعين لشيخ كلّ ناظره ... وصغّر الخطّ في ألحاظه الكبر
يرى به صور الأسطار قد عظمت ... كعنصل الماء فيه يعظم الوبر



Diwan ibn Hamdis
(Beirut, 1970)

Ibn al-Hamdis
c. 1056 – 1133 CE
Sicily, Seville, Tunis
"Poet of the Mediterranean"


12th century depiction of a Sicilian Saracen Poet

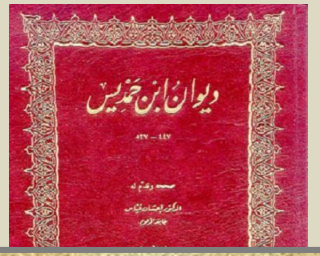
- A solid stream held on the palm / inside it the vision dives via mind's pearls
- It dresses the lines with light when they are dark / as if it is a spring from which light gushes out
- It transparently shows the writings on the book to the eye; transparent like air, but its material is rock
- It leaves a wet trace on cheeks; the trace is like a river drawn by its solidness and sweating
- When my eyes had fatigue, I applied its jewels as eyeliners on them.
  Isn't the vision made sharper with jewels eyeliners?
- It is like a mind of a smart human,
  who is deciphering an obscure cryptograph that is difficult to decipher
- A good aid to an elderly whose vision got weak, and the old age made the writing small on his eyes
- Using it he sees the lines got large, as the water enlarges the fluff of squill

Lutfallah Gari (2008)
MuslimHeritage.com

A 12th Century Poem of Ibn al-Hamdis

يغوص فيه على درّ النهى النظر
كأنه ينبوع نور منه ينفجر
شف الهواء، ولكن جسمه حجر
فيه وقرّ عليها جامدا نهر
أما يُحَدّ بكحل الجوهر البصر؟
من المعمّى عويصا فكّه عسر
وصغّر الخطّ في ألحاظه الكبر
كعنصل الماء فيه يعظم الوبر

د في الكف تحمله
ر ضياء عند ظلمتها
عن خط الكتاب كما
د بجرح نالها عرق
ي إذ كلّت بجوهره
ن ذي حذق يفك به
ن لشيخ كلّ ناظره
الأسطار قد عظمت



Ibn al-Hamdis
c. 1056 – 1133 CE
Sicily, Seville, Tunis
t of the
rranean"

12th century depiction of a Sicilian Saracen Poet

- A solid stream held on the palm / inside it the vis
- It dresses the lines with light when they are dark light gushes out
- It transparently shows the writings on the book t but its material is rock
- It leaves a wet trace on cheeks; the trace is like and sweating
- When my eyes had fatigue, I applied its jewels a
  Isn't the vision made sharper with jewels eye
- It is like a mind of a smart human,
  who is deciphering an obscure cryptograph
- A good aid to an elderly whose vision got weak, ing small on his eyes
- Using it he sees the lines got large, as the wate

Lutfallah Gari (2008)
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Early Evidence for Eyeglasses

1284 Capitulary of the Guild of Crystal Craftsmen (Murano)

Indiction of **April 2, 1300**: Venetian Justices order that no once may buy or sell "any works of white glass which imitate crystal, namely … **disks … for the eyes** *('roidi da ogli')* … and… **stones for reading** *('lapides ad legendum')*, under pain of a penalty of 10 libre…"

But a year later they relented, but only for eyeglasses!

Indiction of **May 15, 1301**: Justices grant any craftsman permission "to make **glass lenses for reading** *('Vitreos ab oculis ad legendum')* , if he will… swear that he will sell the glass as glass.

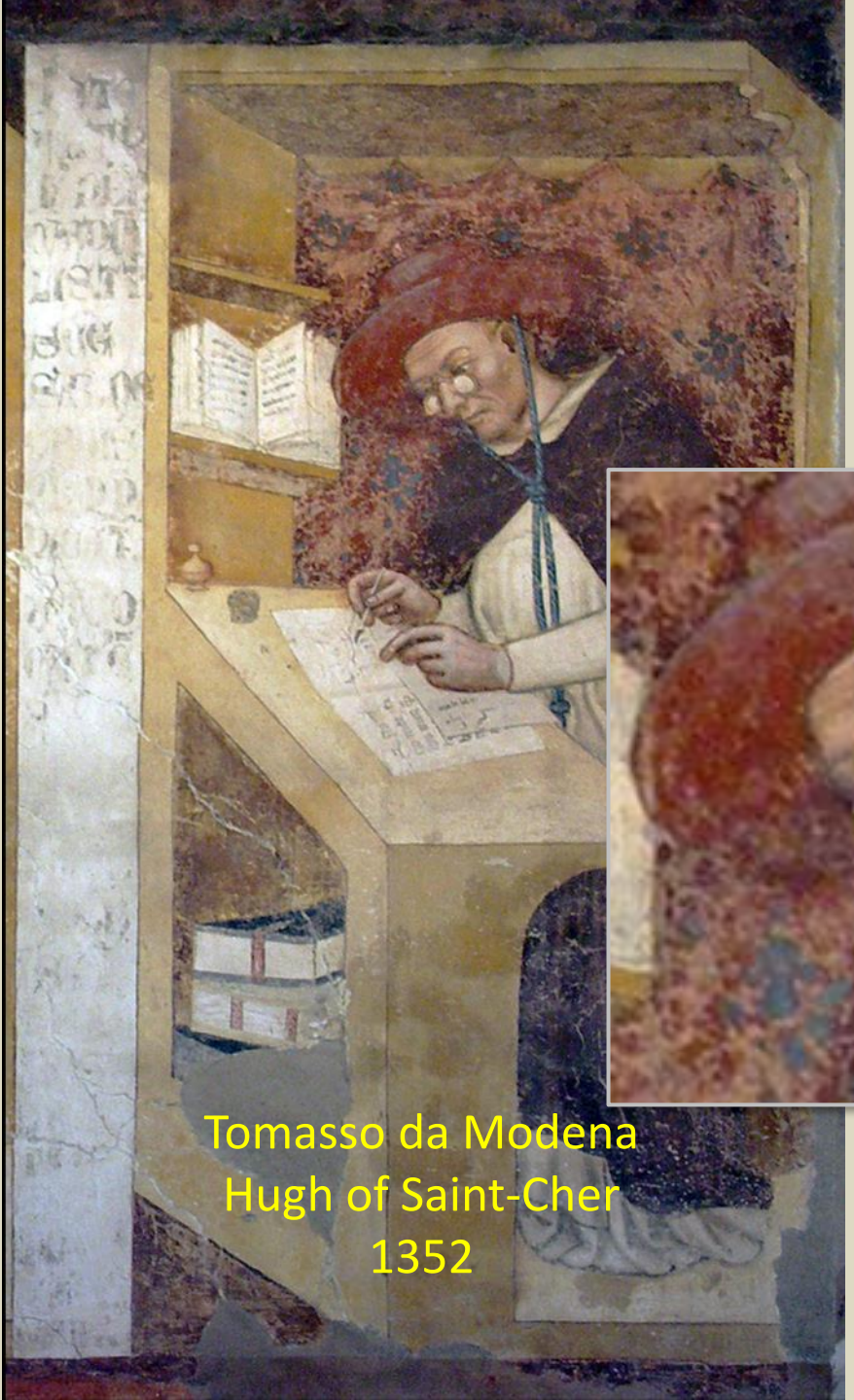
Dennis Romano, *"The Venetian Crystal Workers' Gild in the 13th & 14th Centuries"* Masters Thesis, Rice University (1975)

Tomasso de Moderna

Frescos at
the Chapter House
Convent of San Nicolo
Treviso, Italy
(1352)

40 Dominican Scholars

First depiction of Spectacles in Art



Tomasso da Modena
Hugh of Saint-Cher
1352

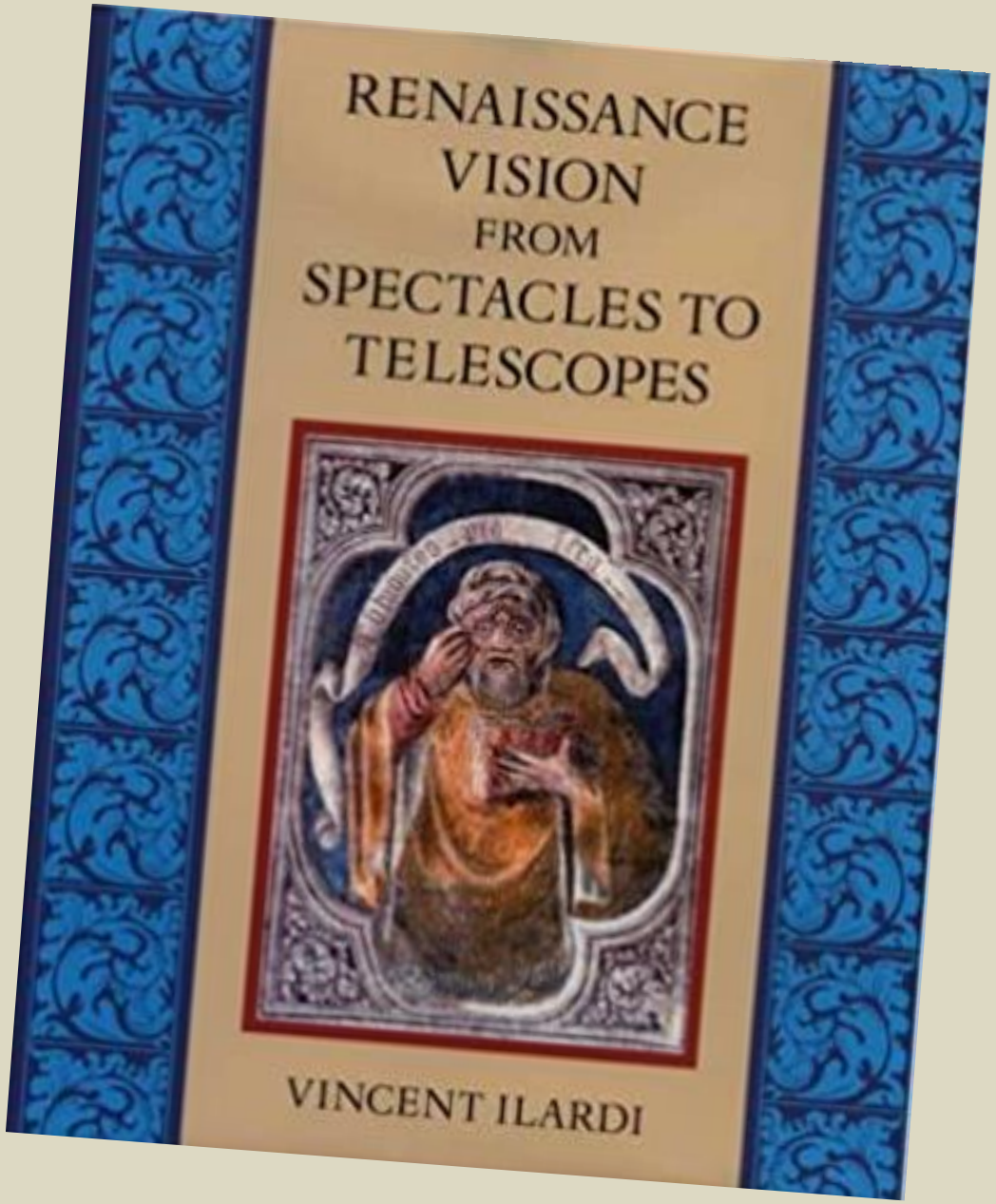
Friar Hugh of Saint-Cher
(c. 1200-1263 CE)

Tomasso da Modena
Cardinal Nicholas of Rouen
1352

Definitive History of Spectacles:

American Philosophical Society
2007

Expensive, but available online at Google Books



1462:

Duke Sforza of Milan orders 3 dozen custom pairs of spectacles, both convex and concave, from Florence.

Cost was ~ half a day's wages of a mason each.

Manufacturing took 1 week.

The Spectacle Vendor

Flemish
1582

Johannes Stradanus, engraving by Johannes Collaert

The Spectacle Vendor

Flemish
1582

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