The Monetary History of the Ottoman Empire

The silver content of the Akçe coins during the reigns of Murad III, Mehmed III and Ahmed I

Manfred Schreiner, Marta Rodrigues

Institute of Science and Technology in Art
Academy of Fine Arts Vienna, Austria
http://www.ntk.akbild.ac.at
In summer 2000 ≈ 60,000 coins were found at the medieval site of Beçin Kalesi in Turkey by Prof. Ünal, Ege University of Izmir.

A large scale international research project has been called into life.
Beçin Kalesi in the area of Milas, south of Izmir
• In summer 2000 ≈ 60,000 coins were found at the medieval site of Beşin Kalesi, in Turkey.

• These coins belong to the Ottoman Empire and were produced during the 16th and 17th centuries under the Sultans Murad III (1574-1595), Mehmed III (1595-1603) and Ahmed I (1603-1617) in several different mints.

• It is the largest hoard ever found in Turkey in total numbers and the most important Ottoman treasure ever discovered.

A large scale international research project has been called into life.
The following institutions take part in this project:

• Ege University, Izmir

• Turkish Academy of Sciences, Ankara

• The Scientific and Technical Research Council of Turkey, Marmara Research Center, Gebze

• Austrian Archaeological Institute, University Vienna

• Numismatic Commission, Austrian Academy of Sciences, Vienna

• Institut für die Kulturgeschichte der Antike, Austrian Academy of Sciences, Vienna

• Kunsthistorisches Museum, Vienna

• Academy of Fine Arts, Vienna
Aims of this interdisciplinary and transnational project:

• prepare a catalogue of the coins (in print: 2009/10)

• perform systematic investigations to confirm the geographical assignment suggested by the numismatists and the provenance of the ore

• present an overview about the monetary history of the Ottoman Empire in the 16th – 17th centuries in close cooperation between numismatists, archaeologists, historians, economists and scientists
Chapter 8 “Debasement and disintegration”, page 131:
“Economic historians generally agree that the fortunes of the Ottoman economy and state finances took a sharp turn for the worse during the closing decades of the sixteenth century. Stability and expansion were replaced by stagnation and crisis, if not contraction.”

page 135:
“The growing fiscal difficulties culminated in the largest debasement to date and one of the largest in Ottoman history that reduced the silver content of the Akçe by 44 percent. (...) The precise date of this operation has not been established. It was undertaken after 1584, most probably in 1585.”
Scientific contribution

- **Was the silver content changed?**
  Determination of the silver content of the Akçe coins
  (characterization of the fineness)

- **Can we assign the coins to various mints?**
  Find clustering concerning the provenance of the coins (mints)
  Determination of trace elements and perform statistical analysis (principal component analysis)

- **Is it an original coin or fake?**
  Characterization of “suspicious” coins
Most of the coins showed a green patina
Clumps of coins in state of excavation
Non-destructive ↔ Non-invasive ?

Requirements for the Analysis of Artifacts

- non-destructive analysis: non-sampling !!
  (non-invasive: no changes of the object !!)
- air path system: no vacuum !!
- transportation of the artifact / instrument
- surface (patina) and bulk analysis
- fast
- costs
Non-destructive analysis of coins by x-ray analytical techniques: XRF, PIXE, Sy-XRF, SEM/EDX, XRD (ND)

XRF – X-ray Fluorescence Analysis
PIXE – Particle (Proton) Induced X-ray Emission
Sy-XRF – XRF by using Synchrotron Radiation
SEM/EDX – Energy Dispersive X-ray Microanalysis in a Scanning Electron Microscope
XRD – X-ray Diffraction Analysis
ND – Neutron Diffraction Analysis
X-Ray Fluorescence Analysis (XRF)

Sample, Object

Primary X-ray Beam

Secondary X-ray Radiation

Detector

X-Ray Tube

Spectrum
Signals caused by the interaction of electrons with material.
Principle of X-ray Fluorescence analysis
(XRF, SEM/EDX, PIXE and SR-XRF)
XRF, PIXE, SR-XRF and SEM/EDX

Advantages
- Non-destructive techniques
- Multi-elemental
- Allow relative short time analyses
- low information depth

Disadvantages
- μ-XRF and specially SEM/EDX,
- low detection limits
Cross-section of a coin: Backscattered electron image

Characteristics X-ray

hv, e⁻, p⁺

Ag- and Cu-rich phases

Obverse

Reverse

100 μm
ultrasound, EtOH/ Komplexone III

State of preservation after excavation
Ag-rich layer

homogeneous layer

primary X-ray beam

Ag-L

Ag-K

Tiroler Kreuzer  100µm
clumps of coins in state of excavation

most of the coins showed a green patina

small samples of ≈ 450 coins were taken

The samples were embedded in synthetic resin, cross-sectioned and polished in order to achieve a flat surface. Investigations were then carried out with μ-XRF, SEM/EDX, PIXE and SR-XRF in order to:

• characterize the type of alloy and fineness of the coinage

• perform statistical analysis (principal component analysis) – find clustering concerning the provenance of the coins (mints).

Permission of the Ministery of Culture in Ankara, Turkey
Mikro X-ray fluorescence (µ-XRF)

• transportable instrument COPRA*

• polycapillary

• beam diameter ca. 0.1 mm (100 µm)

• Mo tube (Oxford Instr.)

• Si-drift detector (Röntec)

*EU-Projekt Nr. SMT4 - CT98 - 2237
Diameter of x-ray beam: \( \sim 100 \, \mu m \)

Focusing the x-ray beam due to **total reflection** in the polykapillary (\( \sim 300,000 \) capillaries)
Principle of Polycapillary

From bulk to micro analysis

X-Ray source

primary radiation

focused

primary radiation

Sample

Lateral resolution measured in cm²

Lateral resolution measured in µm²
COPRA - instrument

Scheme of the COPRA instrument
Why using XRF, PIXE, SR-XRF and SEM/EDX?

Advantages
- Non-destructive techniques
- Multi-elemental
- Allow relative shorted time analyses

Disadvantages
- low information depth
- μ-XRF and specially SEM/EDX, low detection limits

PIXE and SR-XRF – good detection limits
Characterization of the Alloy and Fineness of the Coinage

**XRF:** 35 kV, 0.8 mA
*Spectrum of coin no. 18555*

**SEM/EDX:** 20 kV, 25 – 30 pA
*Spectrum of coin no. 31060*

**Ag, Cu** (major elements) and **Pb, Bi, Au** (minor and trace elements)
Provenance of the Coins

**PIXE**
*Spectrum of coin no. 31153*
Ag, Cu (major elements) and Pb, Bi, Au, Fe, Ni, Zn, As, Hg, Sn, Sb (minor and trace elements)

**SR-XRF**
*Spectrum of coin no. 18634*
Ag, Cu (major elements) and Pb, Bi, Au, Ti, Mn, Fe (minor and trace elements)
Conclusion I

• XRF, µ-XRF, Sy-XRF, PIXE and SEM/EDX
  - are based on the same physical process
  - non-destructive (for coins non-invasive) techniques
  BUT: due to the corrosion phenomena on the surfaces of the coins sampling with cross-sectioning is necessary

• XRF, µ-XRF and SEM/EDX have a low detection limit for trace elements

• Determination of the traces - Sy-XRF, PIXE
Micro X-Ray Fluorescence (μ-XRF)

• Transportable instrument COPRA *

• Mo X-ray tube (Oxford Instruments)

• Si-drift detector (Röntec)

• Focusing unit: Polycapillary lens

• Beam diameter: ca. 0.1 mm (100 μm)

• Quantitative evaluation: WinAxil (Standard-based Fundamental Parameter Method)

• About 150 coins were investigated

* COPRA – A Compact Röntgen Analyser EU Project No STM4-CT98-2237
Coordinator: Prof. Dr. K. Janssens, University of Antwerp, Belgium
Cross section and Spectrum of coin no. 18555

Identified elements: Ag, Cu (major elements) and Pb, Bi, Au (minor elements)
Energy Dispersive X-Ray Analysis in a Scanning Electron Microscope (SEM/EDX)

- **Instruments:**
  - Philips XL 30 ESEM;
  - JEOL JSM-T330A (20 kV)

- **Scanned area for analysis:**
  - 100 x 100 µm² and smaller

- **Quantitative evaluation:** EDAX including ZAF correction

- **About 300 coins were investigated**
Energy Dispersive X-Ray Analysis in a Scanning Electron Microscope (SEM/EDX)

Cross section and Spectrum of coin no. 31060

Identified elements: Ag, Cu (major elements)
Proton Induced X-ray Emission (PIXE)

- PIXE beam time in AGLAE (C2RMF, Louvre, Paris) – within Eu-ARTECH *)
- Beam diameter: ca. 0.1 mm (100 µm)
- Beam energy: 3 MeV
- Detector filters: Low energy – 50 µm Al
  High energy – 50 µm Mo
- Quantitative evaluation: GUPIX (non-linear least-squares fit)
- About 100 coins were investigated

*) Project funded by the European Union
Synchrotron Radiation X-ray Fluorescence Analysis (SR-XRF)

- BAMline at BESSY II in Berlin/Germany
- Dual-Multilayer-Monochromator (W/Si) or Dual-Crystal-Monochromator - Si (111)
- Excitation energy:
  - 18 keV, Si/Li- Detector (45°),
  - 23 keV, HpGe-Detektor
- Beam diameter: 1x1 µm² – 80x15 mm²
- Samples are mounted in air on xyz-stage
- Long distance Microscope
- About 415 coins were investigated
# Results

**μ-XRF, SEM/EDX, PIXE and SR-XRF**

<table>
<thead>
<tr>
<th>Coin No</th>
<th>µ-XRF</th>
<th>SEM/EDX</th>
<th>PIXE</th>
<th>SR-XRF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ag %</td>
<td>Cu %</td>
<td>Ag %</td>
<td>Cu %</td>
</tr>
<tr>
<td>31138</td>
<td>97,10</td>
<td>2,90</td>
<td>94,80</td>
<td>3,83</td>
</tr>
<tr>
<td>31147</td>
<td>94,61</td>
<td>5,39</td>
<td>92,07</td>
<td>6,20</td>
</tr>
<tr>
<td>31144</td>
<td>89,24</td>
<td>10,76</td>
<td>85,96</td>
<td>13,09</td>
</tr>
<tr>
<td>31054</td>
<td>96,53</td>
<td>3,48</td>
<td>94,81</td>
<td>3,91</td>
</tr>
<tr>
<td>31050</td>
<td>96,72</td>
<td>3,28</td>
<td>95,03</td>
<td>3,98</td>
</tr>
<tr>
<td>31056</td>
<td>96,98</td>
<td>2,72</td>
<td>95,20</td>
<td>4,06</td>
</tr>
<tr>
<td>31119</td>
<td>94,54</td>
<td>5,46</td>
<td>91,40</td>
<td>8,23</td>
</tr>
<tr>
<td>31114</td>
<td>92,50</td>
<td>7,50</td>
<td>87,92</td>
<td>11,54</td>
</tr>
<tr>
<td>31112</td>
<td>96,25</td>
<td>3,76</td>
<td>92,92</td>
<td>5,95</td>
</tr>
<tr>
<td>31116</td>
<td>94,27</td>
<td>5,34</td>
<td>91,68</td>
<td>7,20</td>
</tr>
<tr>
<td>18480</td>
<td>88,86</td>
<td>11,14</td>
<td>85,61</td>
<td>13,55</td>
</tr>
<tr>
<td>18463</td>
<td>89,68</td>
<td>10,32</td>
<td>83,65</td>
<td>15,32</td>
</tr>
<tr>
<td>18468</td>
<td>94,65</td>
<td>5,35</td>
<td>92,83</td>
<td>6,25</td>
</tr>
<tr>
<td>18472</td>
<td>95,50</td>
<td>4,51</td>
<td>91,84</td>
<td>6,61</td>
</tr>
<tr>
<td>18469</td>
<td>86,45</td>
<td>13,56</td>
<td>81,92</td>
<td>16,77</td>
</tr>
</tbody>
</table>
µ-XRF Results

Comparison of the Ag % in Akçe coins
Map of 18 mints during the Ottoman periods (1574 – 1617)
Comparison of the Ag % in Akçe coins
Comparison of the Ag % in Akçe coins

PIXE Results
SR-XRF Results

Comparison of the Ag % in Akçe coins
Diagram with the average silver content for each mint
Debasement of Silver?

Chemical composition of the Akçe coins produced during the 16th and 17th centuries in several mints:  92 – 97 %Ag

Murad III (1574 - 1595):  93.39 %
Mehmed III (1595 - 1603):  93.80 %
Ahmed I (1603 - 1617):  93.05 %

No debasement of the Akçe coins could be determined in contrast to the economic historians.
Chapter 8 “Debasement and disintegration”, page 131:
“Economic historians generally agree that the fortunes of the Ottoman economy and state finances took a sharp turn for the worse during the closing decades of the sixteenth century. Stability and expansion were replaced by stagnation and crisis, if not contraction.”

Page 135:
“The growing fiscal difficulties culminated in the largest debasement to date and one of the largest in Ottoman history that reduced the silver content of the Akçe by 44 percent. (…) The precise date of this operation has not been established. It was undertaken after 1584, most probably in 1585.”
What has changed during these periods is the size and weight of the coins under Murad III (1574 - 1595):

around 1575 – 450 Akçe coins were cut off from 100 dirhem pure silver → 0.68g each coin

around 1600 - 800 Akçe coins were cut off from 100 dirhem pure silver → 0.38g each coin

→ reduction of 44 % of the weight of Akçe coins
Comparison of the trace element pattern of Bi, Pb and Au of some of the coins from Canca, Edirne, Güzelhisar, Novaberde and Sidrekapsi
## Statistical Evaluation (PCA)

<table>
<thead>
<tr>
<th>Cluster 1:</th>
<th>Sidrekapsi</th>
<th>Mehmed III and Ahmed I: 1595 – 1617</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 2:</td>
<td>Canca</td>
<td>Murad III: 1574 – 1595</td>
</tr>
<tr>
<td></td>
<td>Novaberde</td>
<td>Murad III, Mehmed III and Ahmed I:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1574 – 1617</td>
</tr>
<tr>
<td></td>
<td>Sidrekapsi</td>
<td>Murad III: 1574 – 1595</td>
</tr>
<tr>
<td>Cluster 3:</td>
<td>Edirne</td>
<td>Murad III, Mehmed III and Ahmed I:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1574 – 1617</td>
</tr>
<tr>
<td>Cluster 4:</td>
<td>Ankara</td>
<td>Murad III, Mehmed III and Ahmed I:</td>
</tr>
<tr>
<td></td>
<td>Güzelhisar</td>
<td>1574 – 1617</td>
</tr>
<tr>
<td>Cluster 5:</td>
<td>Canca</td>
<td>Mehmed III and Ahmed I: 1595 – 1617</td>
</tr>
<tr>
<td></td>
<td>Sidrekapsi</td>
<td>Murad III: 1574 – 1595</td>
</tr>
</tbody>
</table>

**Problem / Limitation** - old coins were collected, re-melted and minted under the new Sultan
Comparison of the Ag % in Akçe coins
Discussion of the Results

*How to explain the Outliers?*

- Contemporary forgeries
- Mints corrupted due to decline of control

Judging for style - non of the outlier coins appears to be unofficial. Therefore, the reason for the low Ag content cannot be that they were made outside the regular mint.

It is possible that they were the result of some fraudulent activities within the mint itself, i.e. the mint personnel could have stricken coins of lower fineness, but using official minting equipment and original dies.
Is it a fake?

Obverse and reverse of an Akçe coin of the period of Ahmed I: core (95 % Cu, 3% As) was plated with silver foil (92 % Ag, 7 %Cu) → Fake!
Obverse and reverse of an Akçe coin of the period of Ahmed I: core (95% Cu, 3% As) was plated with silver foil (92% Ag, 7% Cu) → Fake!
Obverse and reverse of an Austrian ½ Guldiner of the period of Ferdinand I (1521 - 1564): The core (pure Cu) was plated with a silver foil (95% Ag, 2% Cu) using pure tin as solder material.
Techniques for foil plating around a metal core

Metal core: Cu
Silver foil
Solder material: Sn, Pb, Ag, Cu
The Taler of Ferdinand of Austria

?? Original ←→ Copy ??
The Taler of Ferdinand of Austria

genuine

(minted)

copy

(cast)
Is it a fake?

Coins are made by
- punching
- rolling

Copies/Fakes are produced by
- forming a replica
- casting a counterfeit
Technology of the „Taler“ production

Ag-Cu alloy → sheet → rolling → „Zain“ → cutting
Phase diagram of the system Ag-Cu

Micrograph of a cast coin

Micrograph of a minted coin
Analytical Techniques for non-destructive (non-invasive) texture analysis?

- X-ray diffraction
- Neutron diffraction
X-ray diffraction – Neutron diffraction

- Neutrons scatter at atoms independent of Z
- Higher sensitivity for light elements (H)
- Larger differences in the diffraction pattern between neighbour elements
- Differences between isotopes of the same element
- Low interaction of the neutron with the nucleus → high transmission!
Neutron diffraction – X-ray diffraction

😊 non-destructive even for biological or polymer material

😊 Neutrons (at ISIS) cover an energy range, which corresponds atomic distance (0.05 – 20Å).
   → wide field of applications (from H₂ to macromolecules)

😊 measuring of micromagnetic structures

😊 residual radioactivity

😊 large instrument
Rutherford Appleton Laboratory ISIS Facility

Synchrotron

Proton beam line

Target Station

Ionsource

Rotax
goniometer

coin wrapped in Al-foil
JUelicher LLinear Ortsauflösender Szintillationsdetektor (JULIOS)

Typ B (geöffnet)

Glasblock
Lichtkegel
Neutron
Neutronenszintillator
Photomultiplier
**Time Of Flight (TOF)**

TOF from the source to the detector (approx. 1-20 ms)

\[
\begin{align*}
\nu &= \frac{L}{t} \\
E &= \frac{m \cdot \nu^2}{2} \\
E &= \frac{h \cdot c}{\lambda} \\
n \cdot \lambda &= 2d \cdot \sin \Theta
\end{align*}
\]

\(m = 1.675 \times 10^{-27} \text{ kg}\)  
\(h = 6.626 \times 10^{-34} \text{ Js}\)  
\(c = 2.99 \times 10^8 \text{ ms}^{-1}\)
205518: Summe aller 36 Diagramme (phi=0–350 deg) bei omega=145 deg

normalised counts

Cu(222)  Cu(311)  Cu(220)  Cu(200)  Cu(111)

Al(400)  Al(311)  Al(220)  Al(200)  Al(111)

d-spacing [Å]
Ag/Cu 80:20 coin

detector at 40 deg
omega = 20 deg
chi = 43.2 deg
Conclusion II

• XRF, µ-XRF, Sy-XRF, PIXE and SEM/EDX
  non-destructive (for coins non-invasive) techniques
  BUT: due to the corrosion phenomena on the surfaces of the coins
  sampling with cross-sectioning is necessary

• Determination of the traces - Sy-XRF, PIXE

• No debasement of the silver content BUT reduction of the size
  and weight of the Akçe coins could be determined

• Provenance is difficult due to the fact that coins were collected
  and re-used for new coin productions

• Originality (Authenticity) – texture analysis by microscopy or
  neutron diffraction analysis
Acknowledgments

• Marta Rodrigues, PhD-student at the Institute of Science and Technology in Art, Academy of Fine Arts Vienna
• Dr. M. Melcher – statistical analysis
• Dr. Zich and Dr M. Mäder (μ-XRF measurements)
• Prof. Wernisch and Monica Waas, Institute of Solid State Physics, Vienna University of Technology (SEM/EDX)
• Dr. J. Salomon and Dr. M. Guerra, Laboratory AGLAE in Louvre, C2RMF, Paris (PIXE)
• Dr. M. Radtke and Dr. B. Müller, Lab. BAM (Federal Institute for Materials Research and Testing, Bessy) Berlin (SR-XRF)
• Dr. M. Alram and Dr. N. Schindel (Numismatic Commission)
Dr. Winfried Kockelmann
University of Bonn/Germany,
at ROTAX installed at ISIS,
Rutherford Appleton Lab.,
Oxfordshire/GB