I neutroni come sonda per l'indagine dei beni culturali

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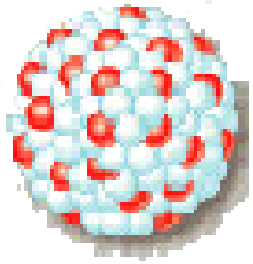
A special thanks to Winfried Kockelmann (ISIS)

The neutron particle

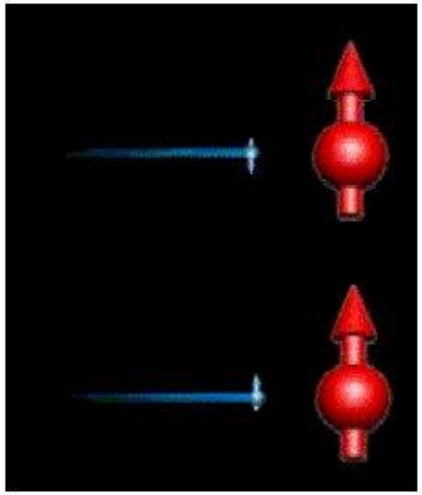


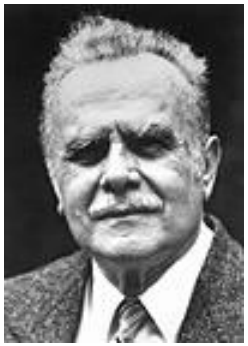
atomic nucleus =
protons + neutrons

- constituent elementary particle of all atoms (except hydrogen)
- limited life time as free particle: $\tau_{1/2} \sim 12$ min

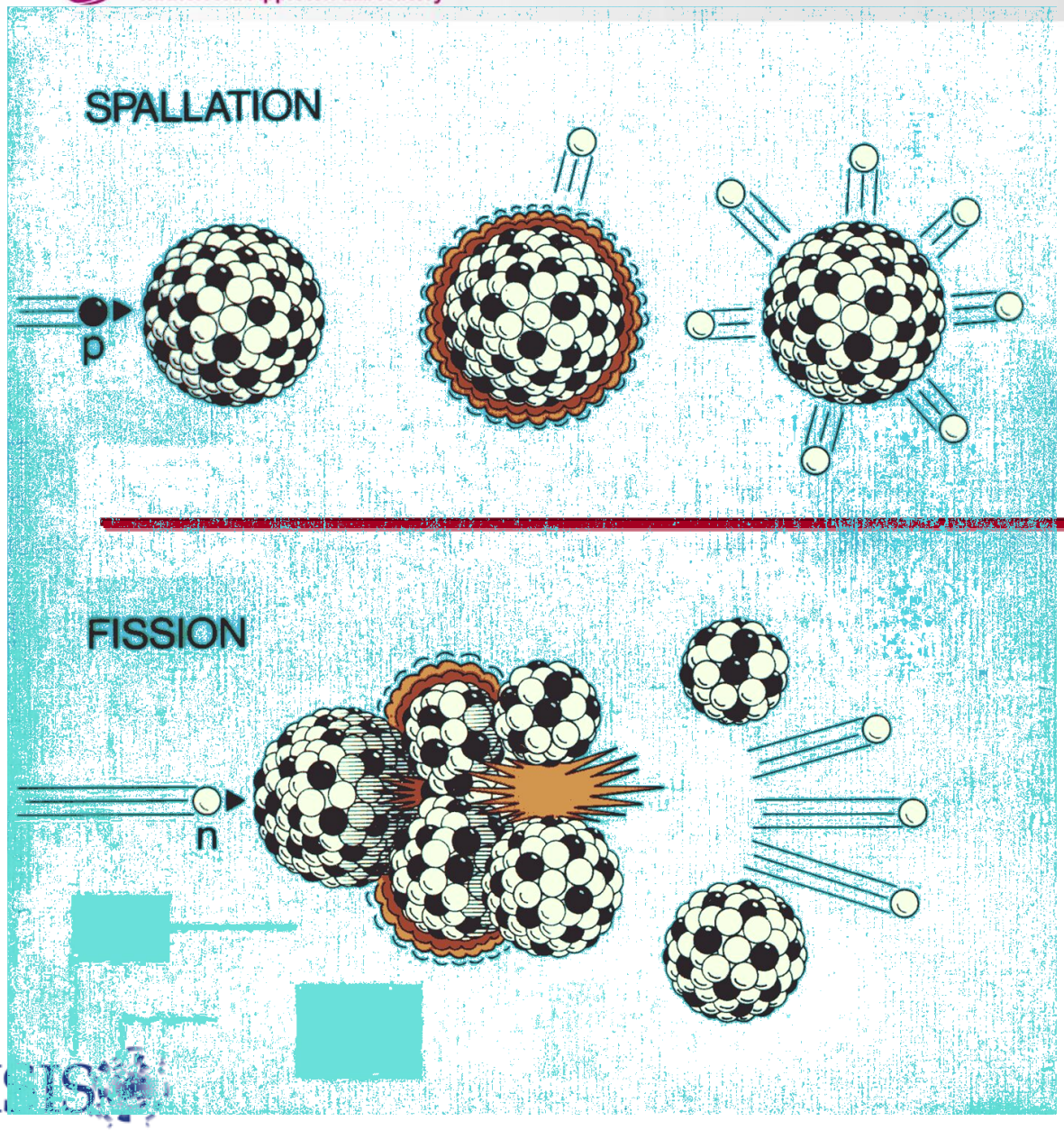
$$n \rightarrow p^+ + e^- + \nu \quad \text{(beta decay)}$$

- mass $m_n = 1.675 \cdot 10^{-27}$ kg
- spin ½ (elementary magnet)
- electrically neutral





Neutron Production



Spallation

- no chain reaction
- pulsed operation
- 30 neutrons/proton

Fission

- chain reaction
- continuous flow
- 1.5 “useful” neutron/fission

Neutrons in Archeological Research

NEUTRONS ARE HIGHLY PENETRATING.

- Non-destructive analysis of large, intact objects
- Radiographic/Tomographic techniques
- Probe length-scale ideally matched to artifacts

MULTIPLE “WINDOWS” INTO THE MATERIALS

- Diffraction (crystal phase composition).
- Strain scanning/Texture (fabrication technique).
- Activation analysis (elemental composition).
- Multiple techniques simultaneously.

1 m

turbine blades

10 cm

Etruscan jug (IV-III BC)

2 cm

Au/Ag coins (Vienna, 16th century)

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Neutron sources

ILL
-nuclear reactor

Institute Laue-Langevin, Grenoble, France

ISIS
spallation neutron source

Rutherford Appleton Laboratory
Chilton, UK

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What kind of objects can be studied?

everything that contains crystalline or amorphous material:

- **ceramics, rocks, marble, (glass), etc**
- **metal objects**

Neutron Diffraction

Diffraction methods are phase sensitive

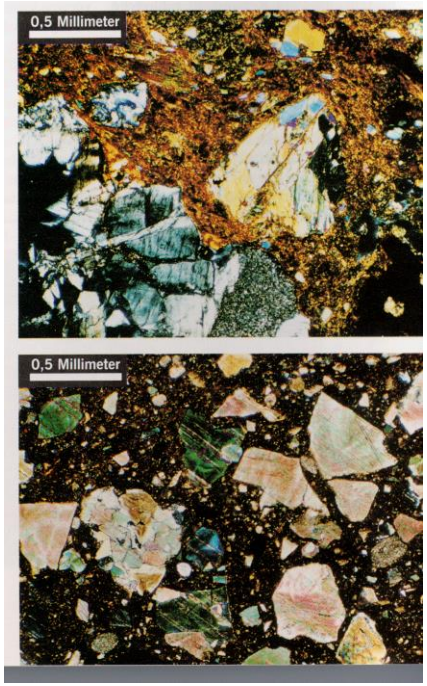
identification and quantitative analysis of phases

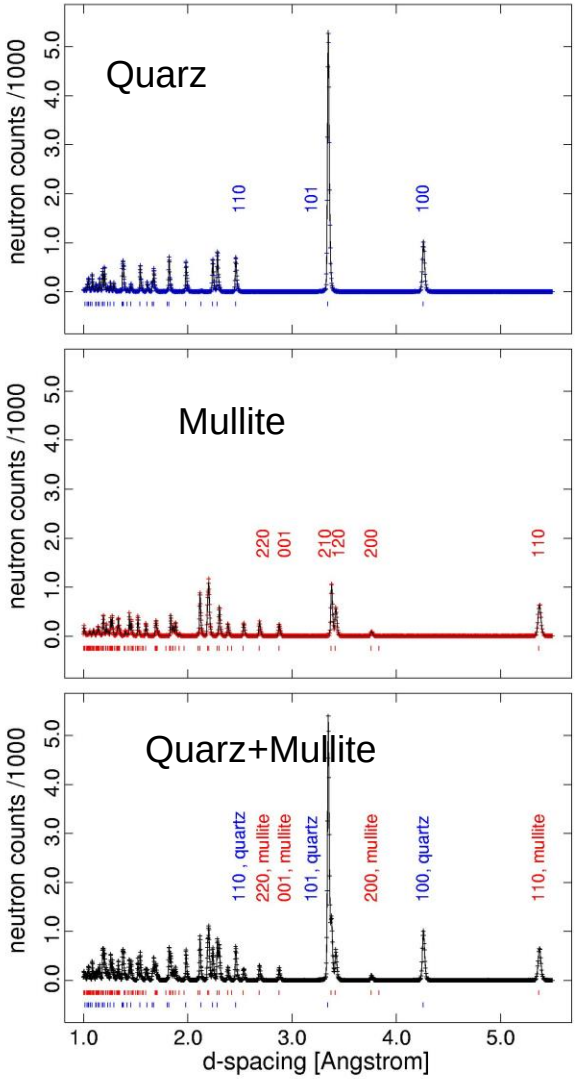
e.g. mineral phases

SiO_2	quartz
SiO_2	cristobalite
SiO_2	glass
$3Al_2O_3\ 2SiO_2$	mullite

e.g. metals, alloys

Cu-Sn, Ag-Cu, Sn-Pb





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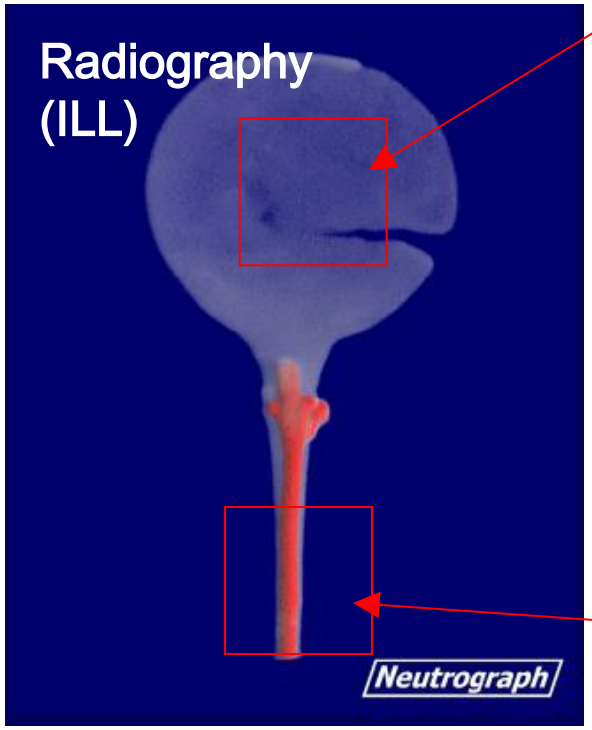
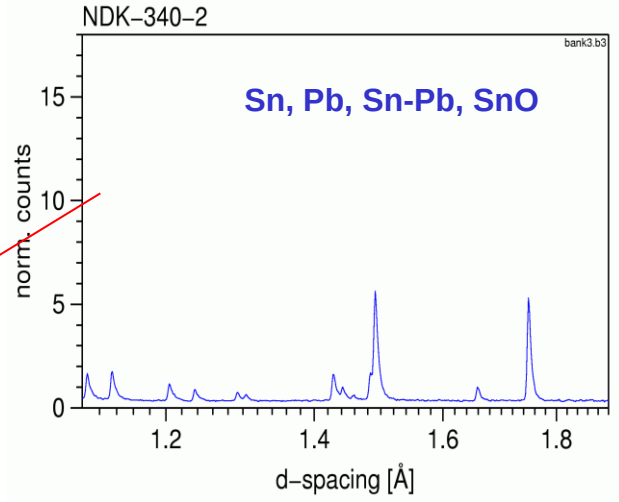
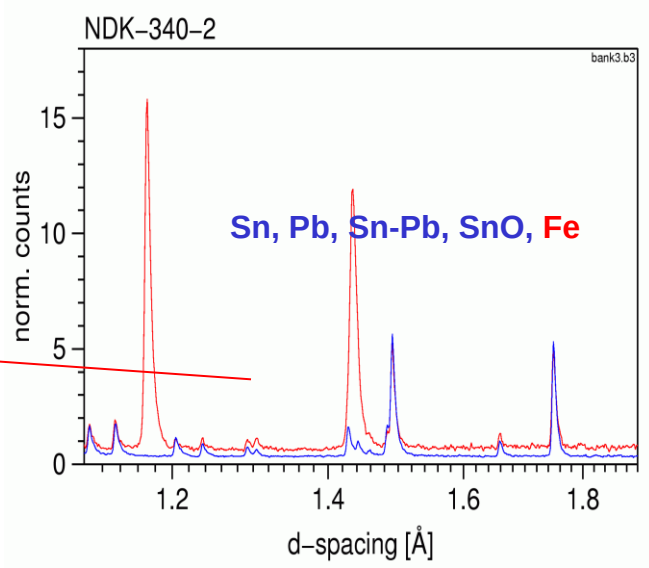
Diffraction and Radiography

Peter Hallebeek, Dirk Visser, Winfried Kockelmann (ICN Amsterdam & ISIS)

14th century Sn spoon, Amsterdam





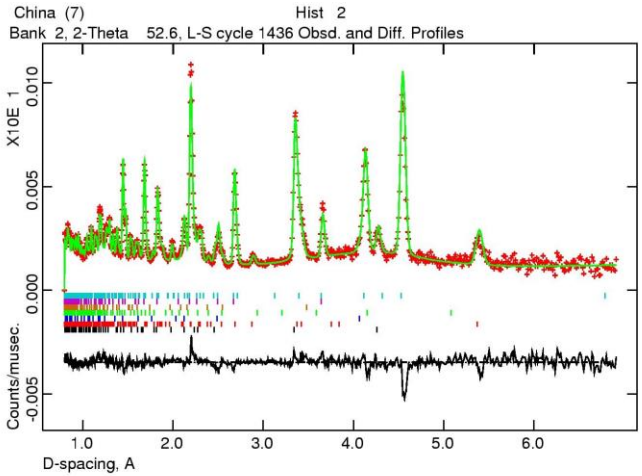


Analysis of 18th century Böttger stoneware

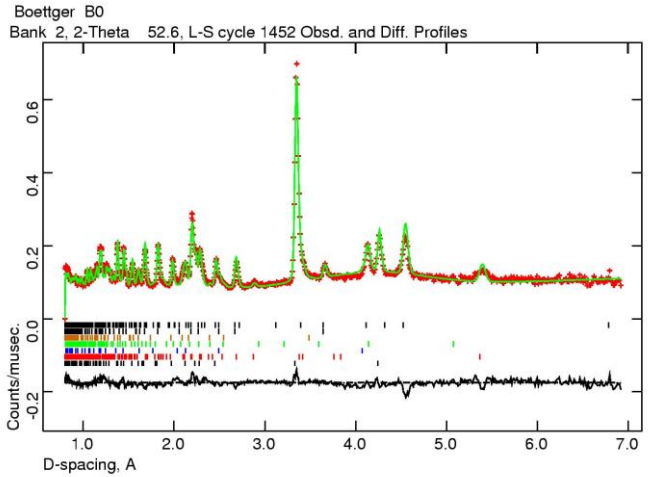
Aim of the project: identify fingerprint of Böttger stoneware by ND & PIXE

Yixing, early 18th century

‚Baluster' vase, Böttger 1712



15%	Quartz	30.3 %
28 %	Mullite	17.7 %
1.4 %	Cristobalite	0.5 %
21.5 %	Glass	33.0 %
1.3 %	Corundum	3.5 %
20.0 %	Hematite	9.1 %



W. Kockelmann
Rutherford Appleton Laboratory,
ISIS, UK

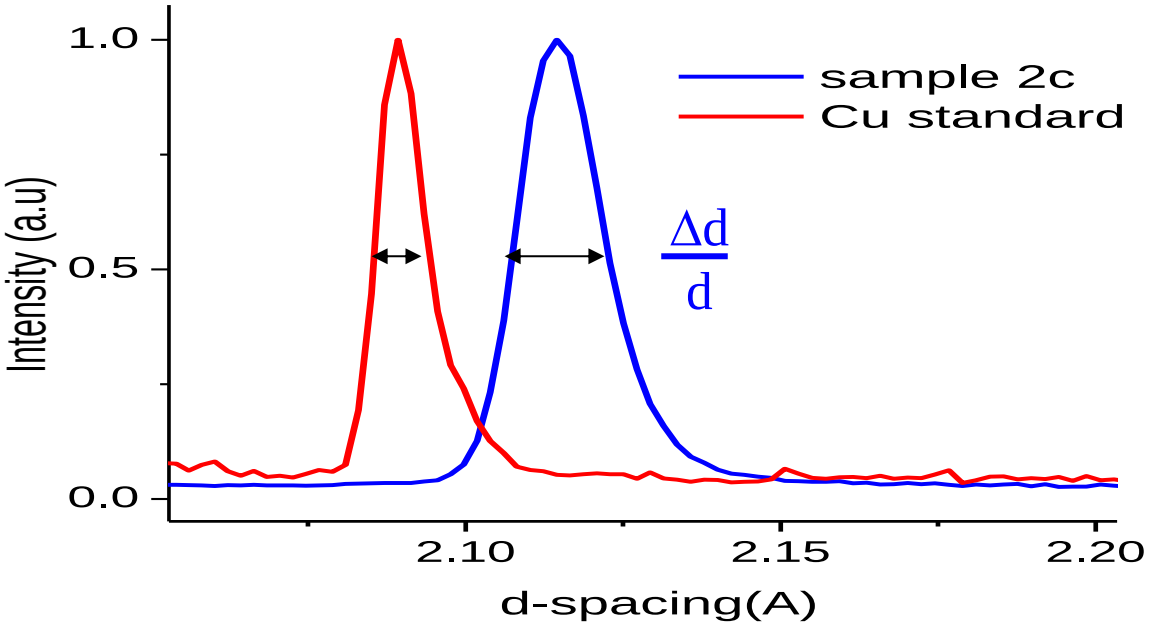
Ch. Neelmeijer, Forschungszentrum Rossendorf
H.-M. Walcha, Porzellansammlung im Zwinger
Staatliche Kunstsammlungen, Dresden

Microstructures and strain analysis

Peak shift ⟺ **Compositional variation or residual stress effects**

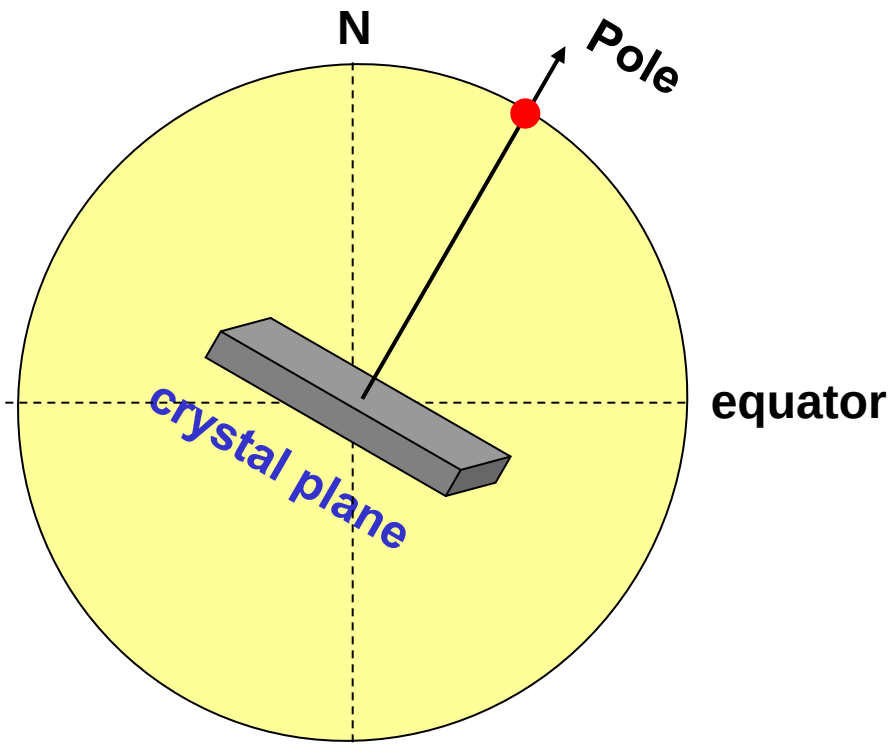
Peak broadening ⟺ **Compositional variation or microstrain or grain size effects**

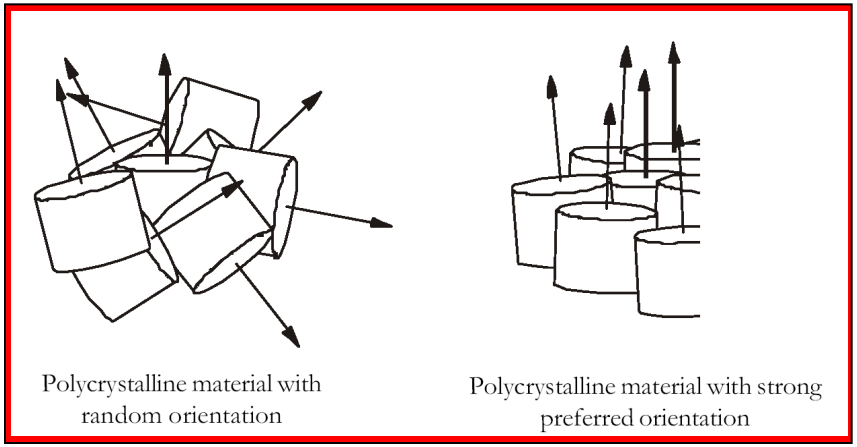
- **Raw casting**
- **Hammering**
- **Annealing**

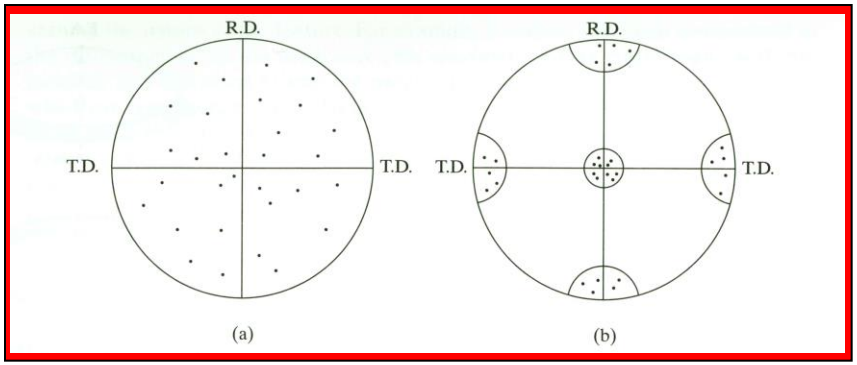


(111) Bragg peak for pure Cu and Cu/Sn bronze

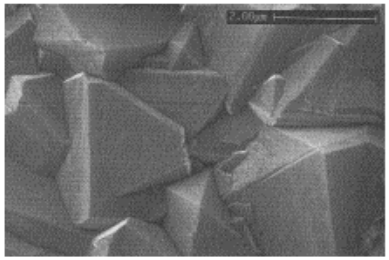
Texture analysis by pole figure collection:
making maps of the crystallite orientation





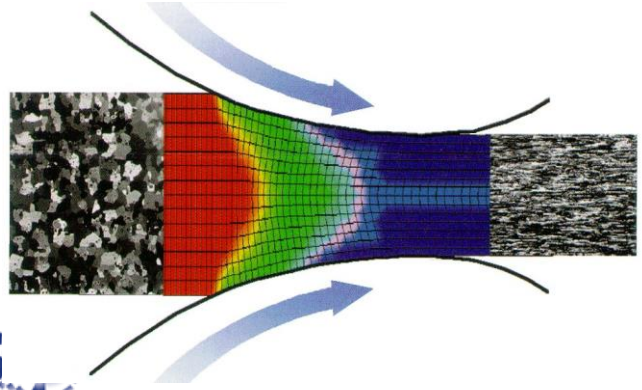


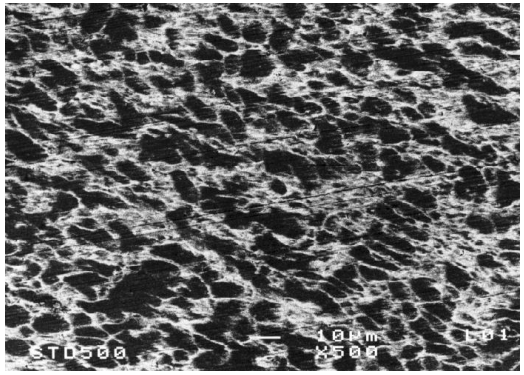
Effect of cold working on texture



The orientation of grains in a material ...

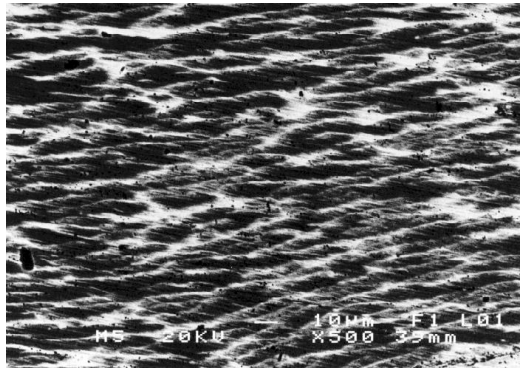
… changes during plastic deformation





cast

no regular texture



rolled

regular texture = preferred orientation of grains

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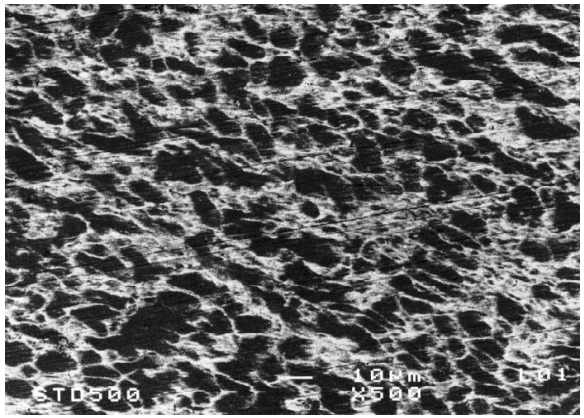
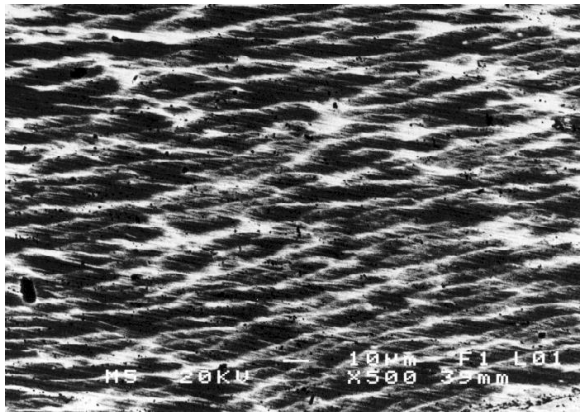
Mapping textures inside the materials

SEM analysis (destructive)



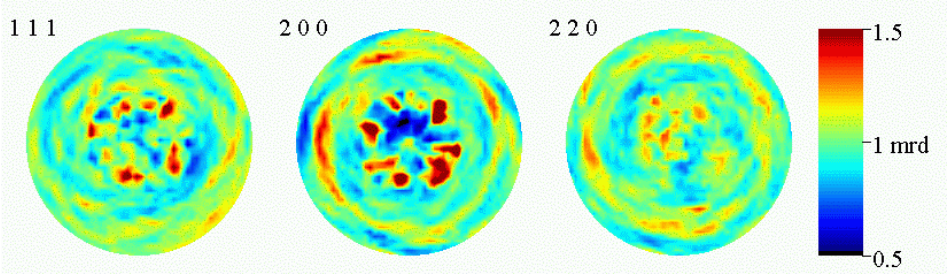
cast



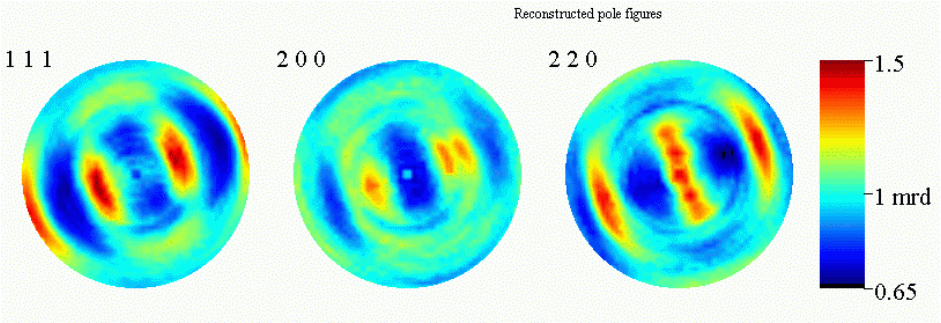
rolled

Neutron texture analysis (non-destructive)

Collection of „pole figures“



Cu, cast



Cu, cold rolled

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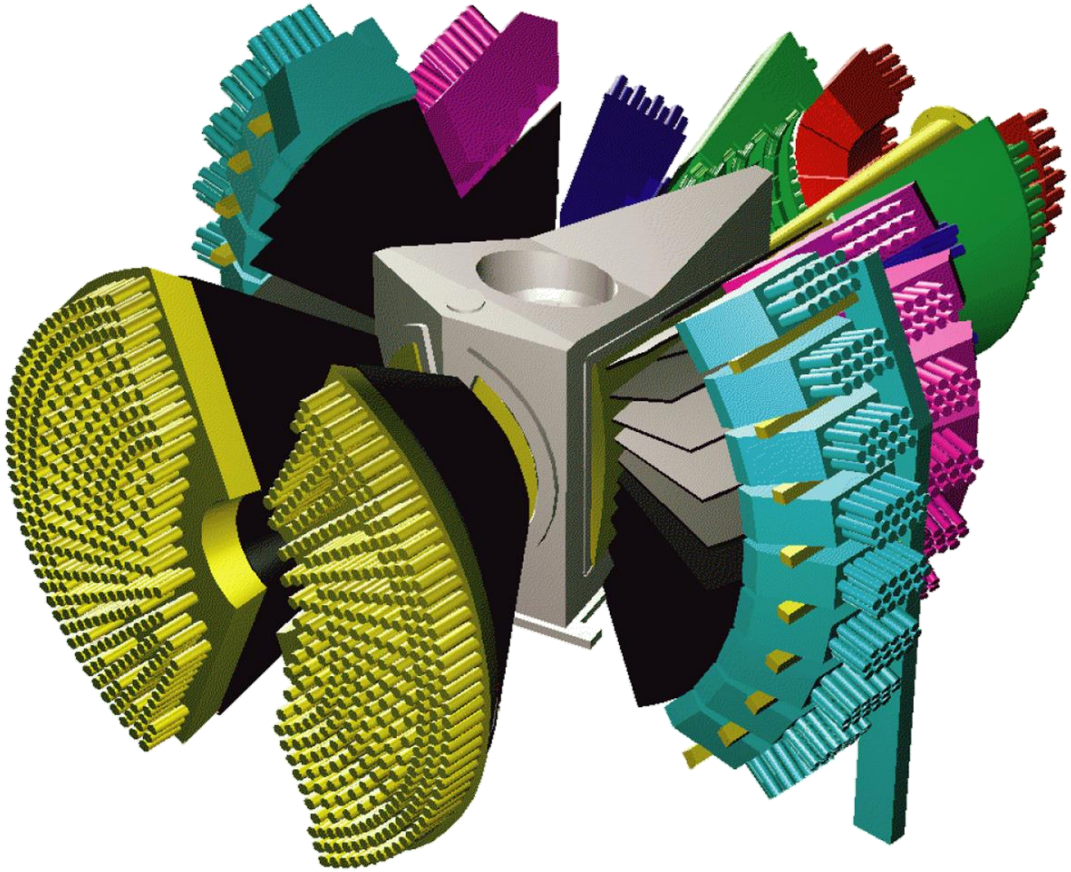
Our “large scale” mapping tools



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Diffraction analysis of a Corinthian-type bronze helmet

Greek bronze helmet, 7th century BC, The Manchester Museum

W. Kockelmann
A.J.N.W. Prag, Roy Garner
E. Pantos

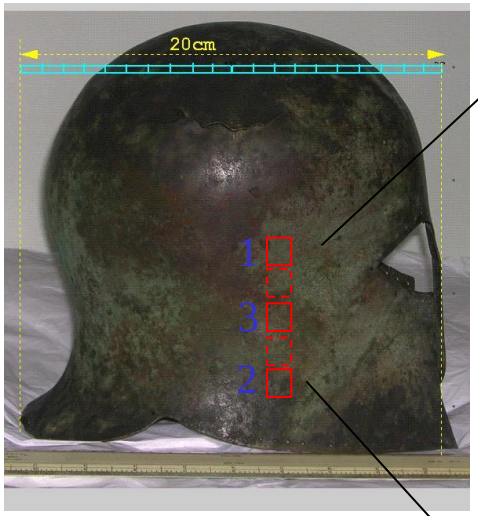
Rutherford Appleton Laboratory, ISIS, UK
The Manchester Museum, Manchester University
Daresbury Laboratory, UK

Aim of the study:

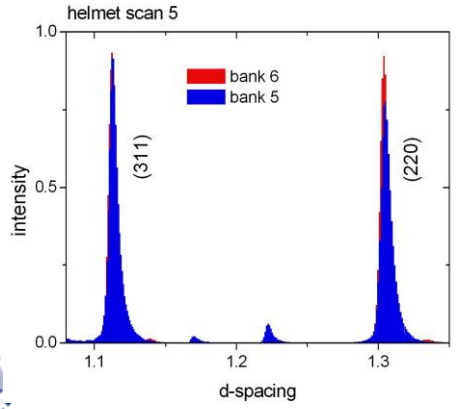
Neutron diffraction: characterise the bulk alloy structure; technological processes involved in manufacturing

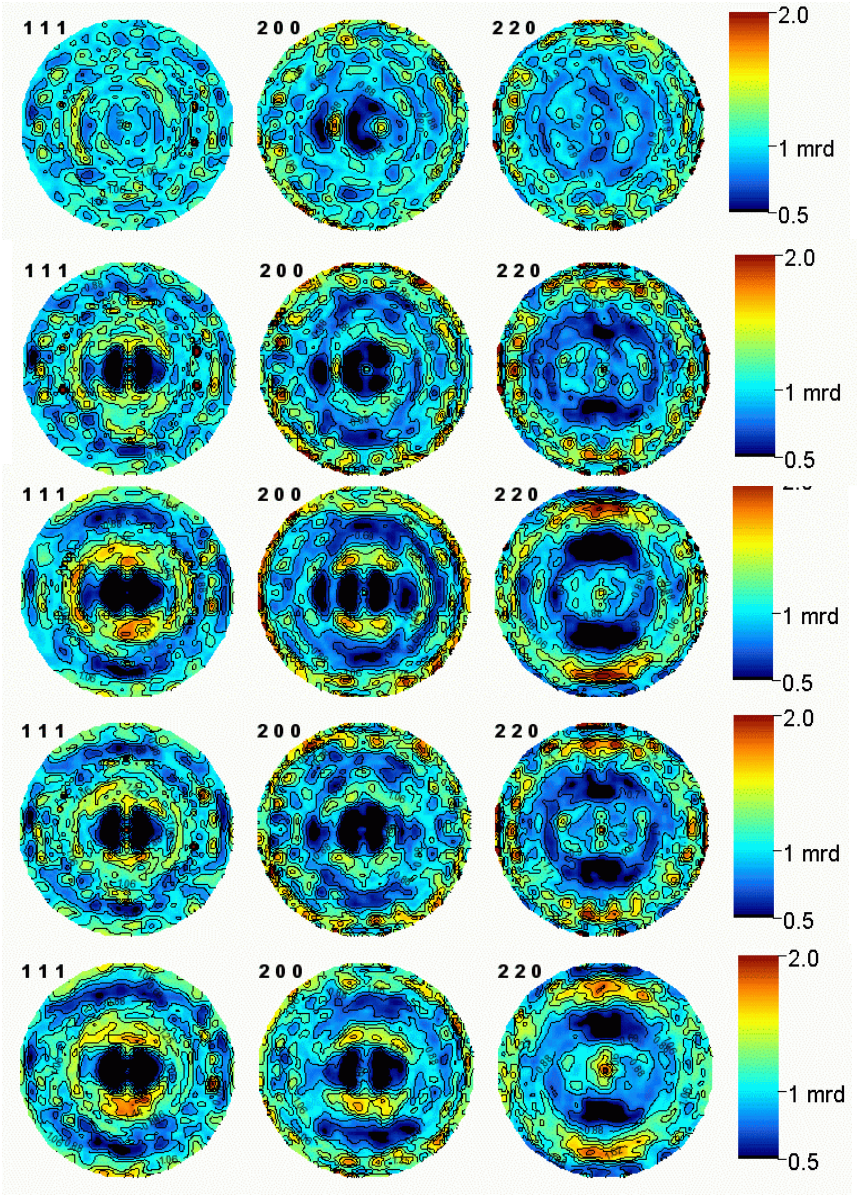
Synchrotron radiation: identify the major and minor elements, corrosion phases, secondary minerals (SRS, Daresbury Laboratory)

Texture Analysis

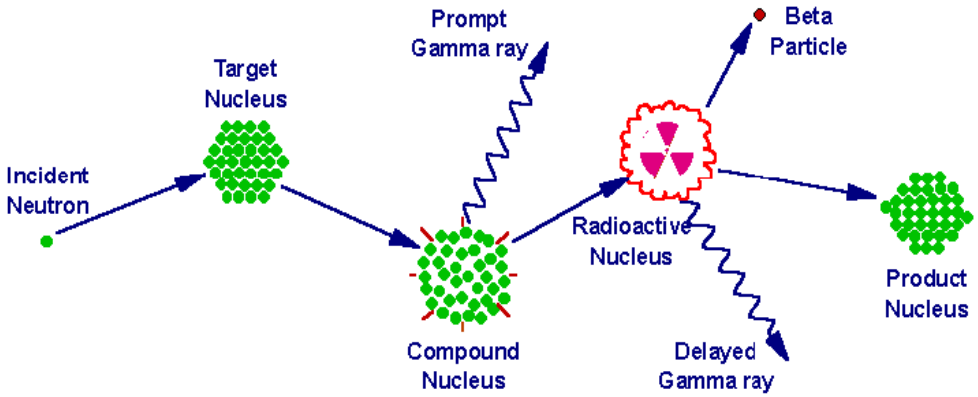


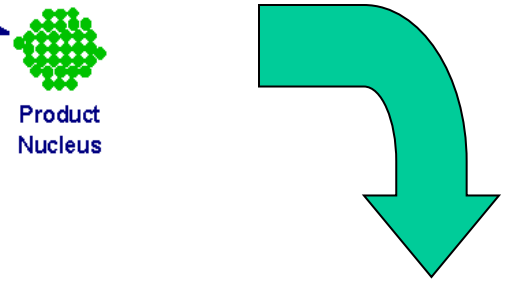
700 BC, Manchester Museum

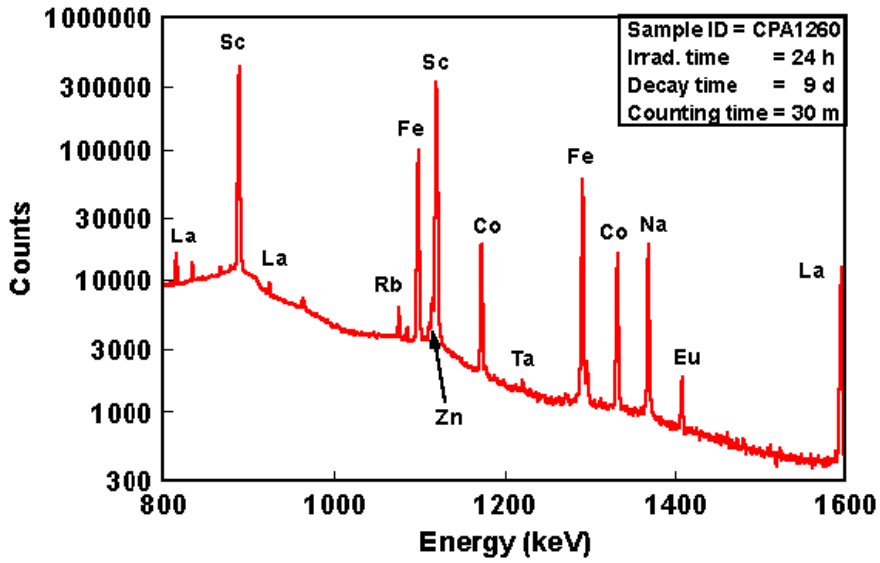




Neutron Activation Analysis



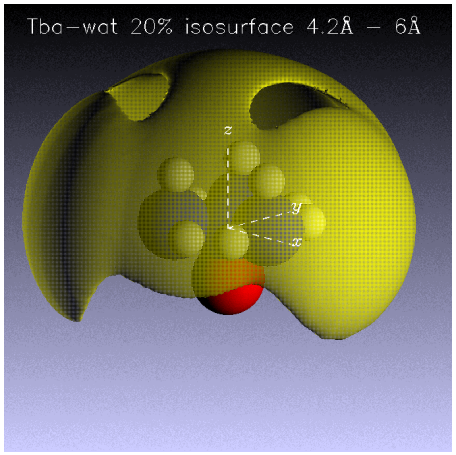




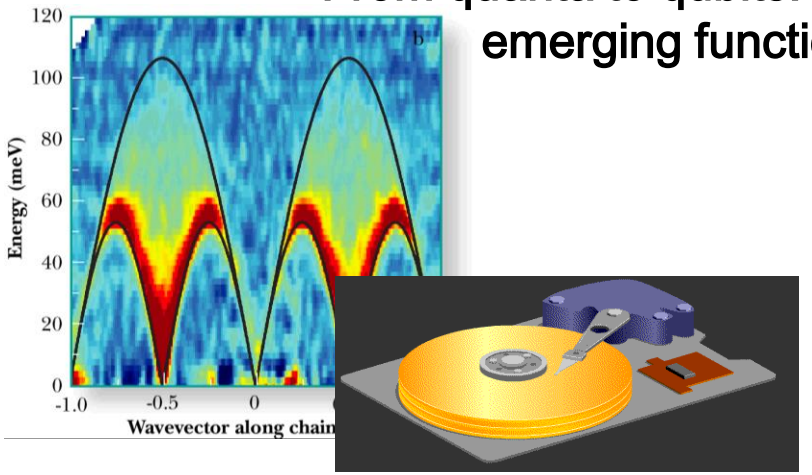
- Trace elements analysis
- Exact localisation of provenance
- Suitable for 3D imaging
- Can be combined with other techniques.

ISIS key themes

Water and life



From quanta to qubits: emerging functionality



Cultural Heritage

The boundaries of life